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ASTRONOMY

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White Dwarfs: Superdense Suns

Is Alien Life Benign?

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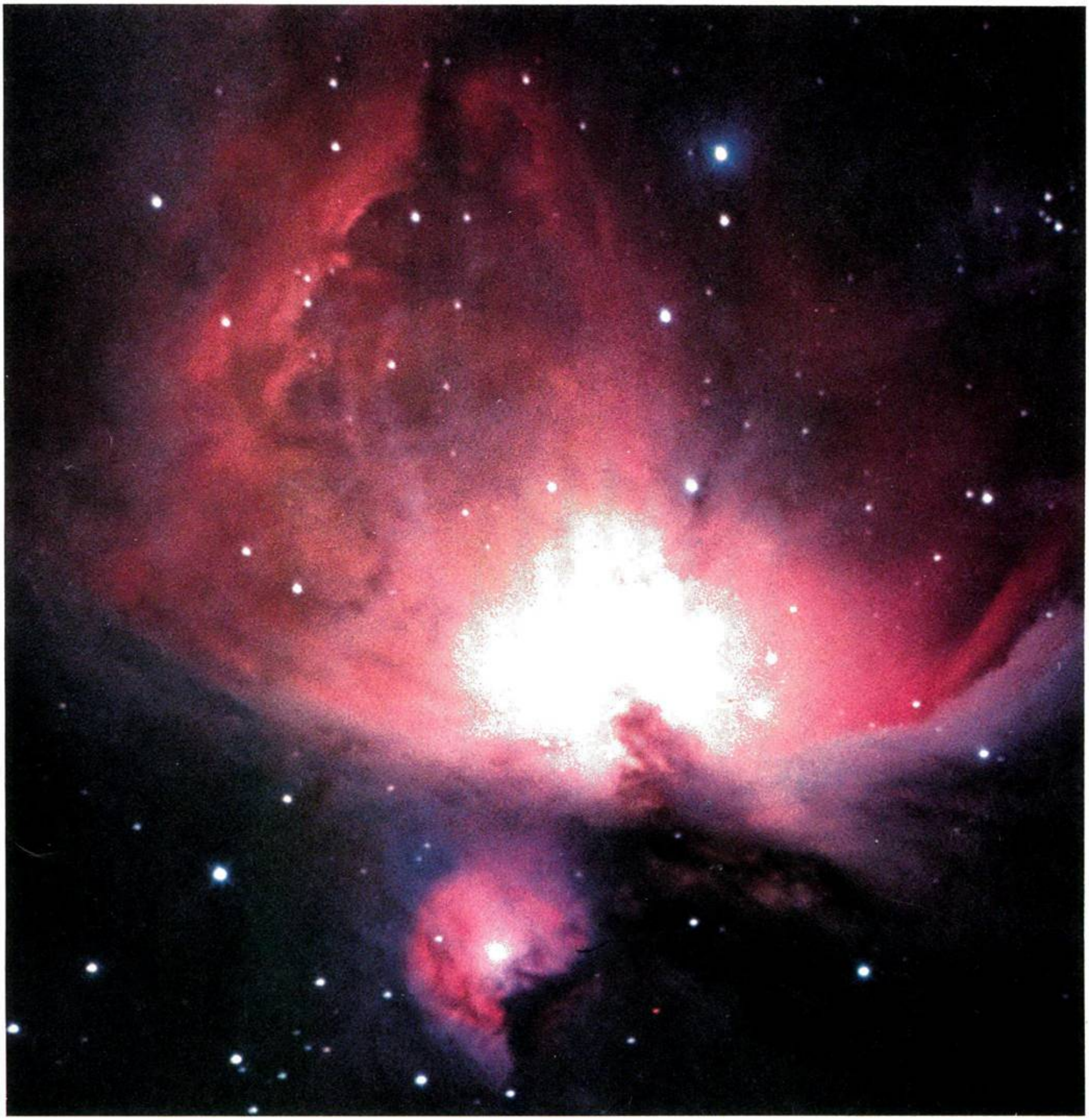

M-42 on VR-1000

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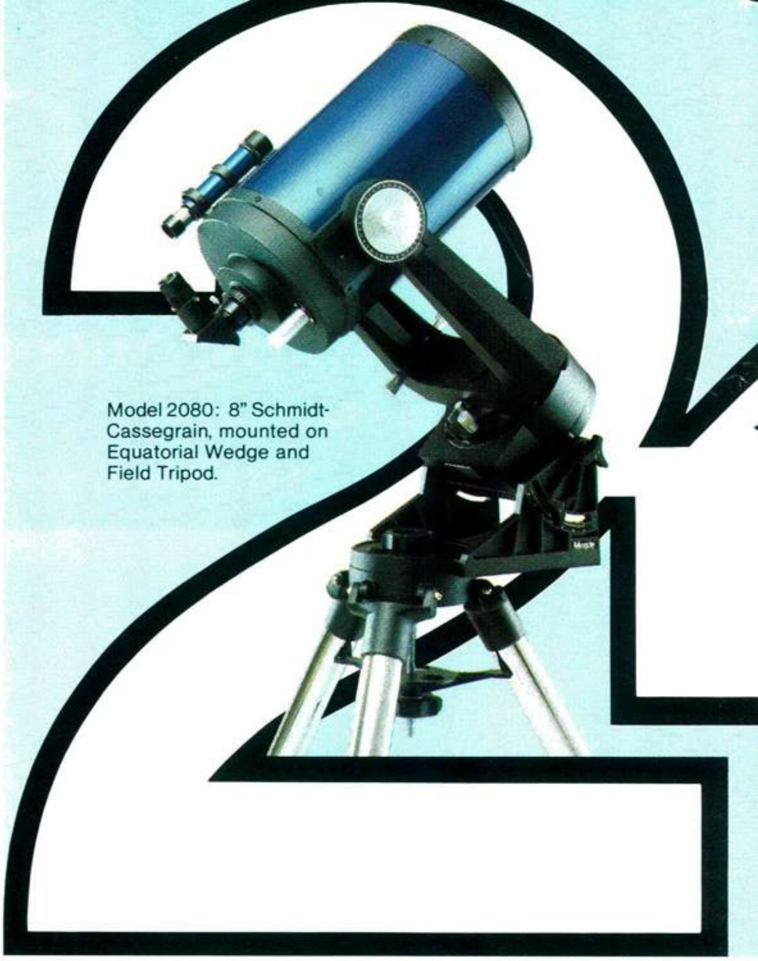
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Cover: The Orion Nebula, M-42, photographed by Jack Newton on "super film" VR-1000. This month, ASTRONOMY takes you into the bizarre realm of white dwarfs, incredibly dense stellar remnants formed during the final days of stars like our Sun. Then we explore backyard astrophotography with VR-1000, and visit the wispy nebulosities of summertime's Swan, Cygnus. Opposite page: The eastern half of the Veil Nebula in Cygnus, NGC-6992/5, also photographed by Newton.

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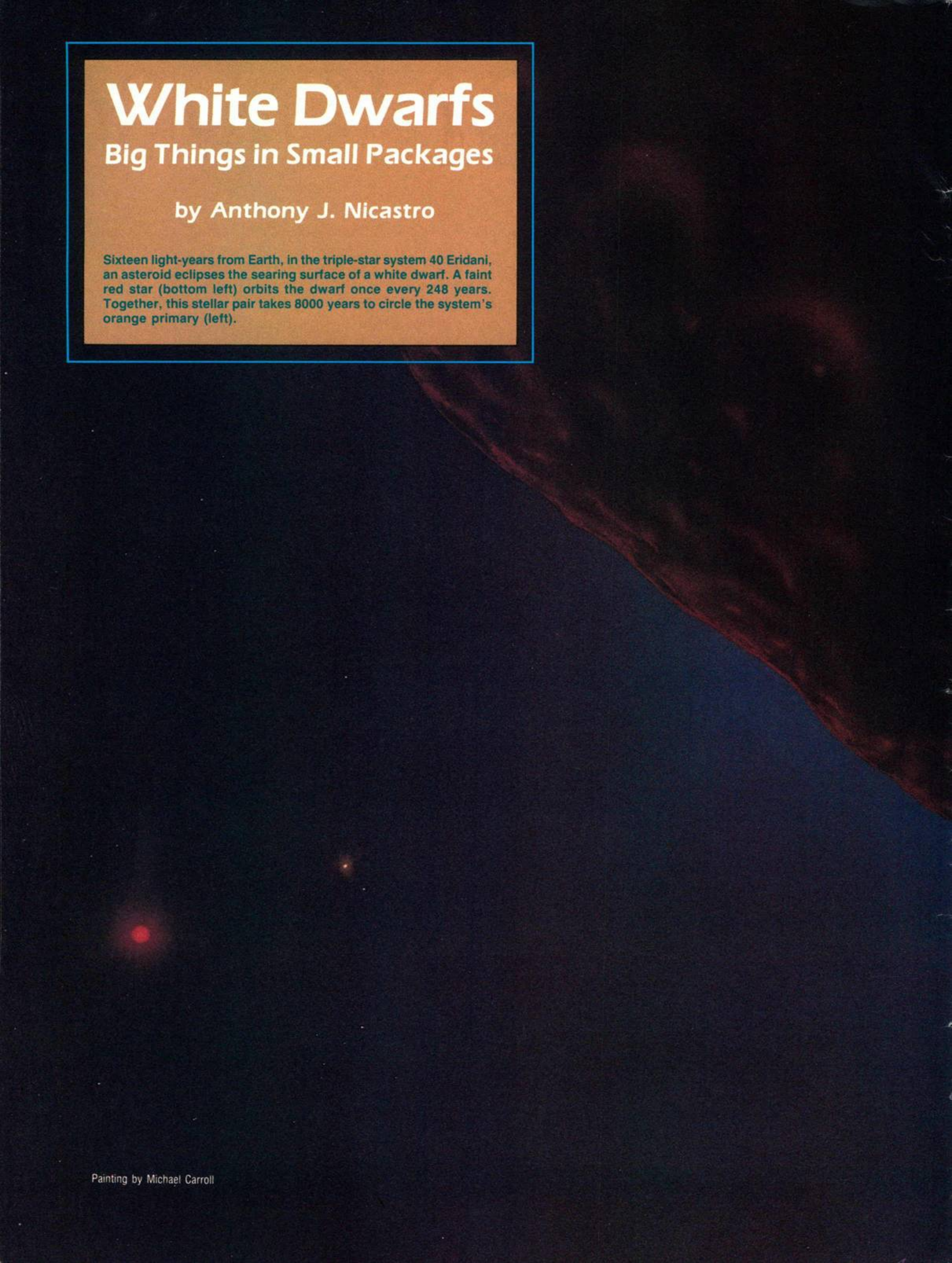
White Dwarfs

Big Things in Small Packages

by Anthony J. Nicastro



Sixteen light-years from Earth, in the triple-star system 40 Eridani, an asteroid eclipses the searing surface of a white dwarf. A faint red star (bottom left) orbits the dwarf once every 248 years. Together, this stellar pair takes 8000 years to circle the system's orange primary (left).

Painting by Michael Carroll

Before the discovery of white dwarfs, astronomers had no clear evidence of the final stages of stellar evolution. Once found, and once their special properties were recognized, white dwarfs provided astrophysicists with a unique laboratory for studying the end of a star's life. But that's not all — these superdense suns helped confirm Einstein's General Theory of Relativity, and paved the way for later work on neutron stars and black holes.

We must, however, discuss white dwarfs in the proper context. They do not form directly out of interstellar gas, but result from material that has undergone billions of years of processing in the core of a Sun-like star. Before we look at white dwarfs, then, we must examine the formation and evolution of the stars from which they form.

The great dark between the stars is filled with enormous clouds of gas. They contain not only atomic hydrogen, the gas that constitutes most of the matter in the universe, but many other gases as well. Tiny solid particles pervade these clouds — stardust composed principally of graphite. You can see some of these dark dust clouds silhouetted against the pale gleam of the summer Milky Way and dividing it in two.

Photographs of dark and bright interstellar clouds deceptively portray a stagnant, unchanging structure. In fact, the material in the clouds is swirling about, its atoms and molecules flying past one another at speeds of many kilometers per second. But each cloud is so incredibly large — many light-years in breadth — that it takes millions of years for any given gas particle to traverse the length of the cloud. And if a particle tries to escape its cloud, the gravity of the mass draws it back in. The result is that the whole thing maintains a loose identity as a distinct structure.

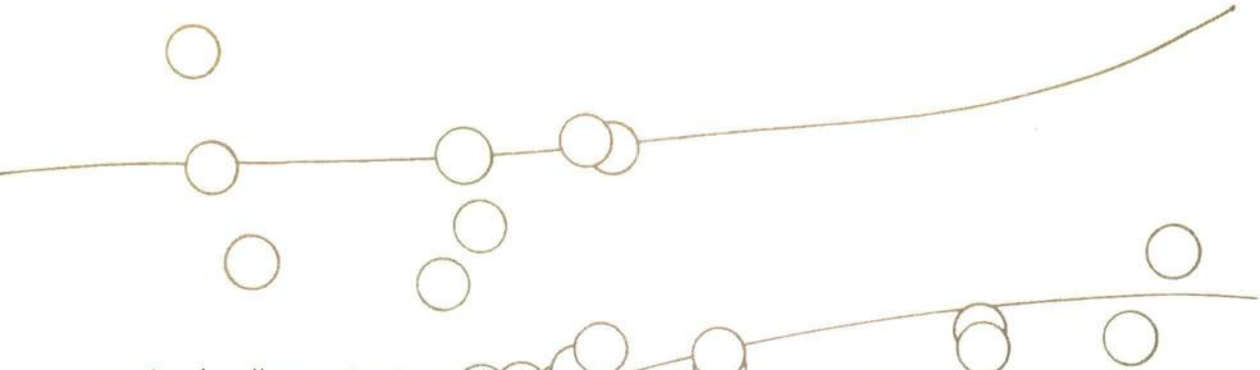
Inexorably, gravity pulls the dispersed matter in on itself, and the cloud shrinks as time passes. But another force opposes the pull of gravity. Collisions between the cloud's constituent particles heat it, increasing its temperature. With the rise in temperature, the cloud's gas exerts a pressure that acts outward. Some of this heat radiates into space, cooling the cloud which contracts further. Once contraction begins, gravity can win out over thermal pressure and the cloud will shrink. As long as the cloud radiates away more heat than its contraction generates, it will continue contracting.

It's unlikely that a cloud would commence gravitational collapse of its own accord; its internal temperature should always provide just enough pressure to keep the cloud from contracting. Astronomers were forced to assume that some shock wave begins the contraction. Bart Bok, in his last article for ASTRONOMY ("A Bigger and Better Milky Way Galaxy," January 1984), wrote: "I had always pictured the collapse of a cloudlet into a protostar as a peaceful phenomenon, mostly gravitational in character. It is now obvious that other, more violent, forces are at work as well."

Imagine a cloud of gas several light-years in size, the inward force of its gravity balanced by the outward push of the cloud's thermal pressure; a quasi-eternal stasis ensues. But then a nearby star explodes, becoming a supernova. The explosion's blast wave, a maelstrom of hot gases and magnetic fields, rushes into interstellar space. As the blast wave hits our cloud, it piles up and compresses the material in its path. Gravity, aided by the blast wave's compression, begins to pull the cloud together. The collapse proceeds quickly, and the cloud grows smaller and hotter. At some critical point, the cloud breaks into several pieces, each of which contracts separately. These collapsing fragments of the original cloud will become individual stars.

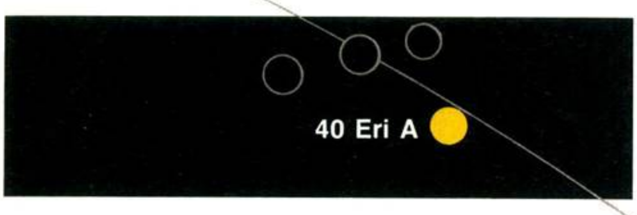
Once a supernova initiates the cloud's collapse, gravity assumes its role as the dominant force in a star's life. Gravity squeezes each protostellar fragment to tremendous temperatures and densities, igniting nuclear fires in its interior that will rage for billions of years. At this point, the cloud fragment has become a star. Gravity tries to make the star contract even further, but if its temperature is sufficiently high, the star's internal pressure pushes outward just enough to balance gravity. Throughout its life, gravity keeps the star's nuclear fires burning, and the energy generated by these reactions produces the pressure that supports the star against gravity's pull. Every star must maintain this precarious balance, somehow generating enough internal pressure to offset gravity's unending attempt to collapse it.

Sooner or later a star must exhaust its supply of nuclear fuel. A star first "turns on" when the nuclei of hydrogen atoms (protons) in its core fuse together, creating the nuclei of helium atoms and releasing energy. When all of the hydrogen in the star's core is converted into helium, hydrogen fusion can no longer take place in the core. The flood of energy-producing heat ceases, the star can no longer support itself, and gravity again dominates. Unable to support its own weight, the star's helium-rich core begins to collapse. The core becomes more and more compressed and its temperature increases. A thin shell of hydrogen wedged between the star's massive outer envelope and its dense core begins to fuse. But since this hydrogen-burning shell lies *outside* of the helium core, the energy generated by the shell cannot prevent the core's



continual collapse. Gravitational compression of the helium-rich core increases its temperature and pressure so much that the violent collisions between helium nuclei cause *them* to fuse, forming carbon and oxygen nuclei and releasing energy. A new thermonuclear reaction — a new energy source — has spared the star any further collapse.

The onset of hydrogen-shell fusion and helium fusion in the core initiates swift, dramatic changes in the structure and appearance of the star. Its size increases by 100 times or more; the color of its surface turns decidedly reddish. The star has become a red giant. At this stage of its life, the star is somewhat unstable and begins to pulsate. A substantial amount of the swollen star's material flows from its surface — over a million years, the star can lose almost as much material as that making up our Sun. This leakage is called a *stellar wind*. No one knows whether the dying star's stellar wind or its slow convulsions are responsible, but the star eventually ejects a sizable fraction of its envelope, puffing off 10 to 20 percent of its mass. When first exposed, the intensely hot core may have a mass less than that of the Sun and a temperature approaching 100,000° K. In comparison, the surface temperature of our Sun is a mere 6000° K. Such a fiercely hot object shines brightly in the ultraviolet part of the spectrum. This high-energy radiation illuminates the gases shed by the star and causes them to fluoresce. The glowing shroud of gas that surrounds a dying stellar core is known as a *planetary nebula*.



A typical planetary nebula has a diameter of about one light-year. Most of the gas shells astronomers now see were ejected within the past 50,000 years, for after this length of time the shell is so enlarged that it becomes too thin and tenuous to remain visible. Planetary nebulae are rare simply because they represent a short-lived, transient phase in the life of a star.

As the expanding nebulosity disappears, the dying central star continues its collapse, radiating away the remaining warmth of its interior. Not hot enough to initiate any further nuclear reactions, the star contracts and stabilizes itself until it is roughly the same size as the Earth. Our star has become a white dwarf — an object of stellar mass and planetary dimensions.

Not all stars are massive enough to undergo all the events described. Stars containing less than about 40 percent of the Sun's mass ($0.4M_\odot$) never get hot enough to initiate helium fusion. Stars holding much more than three times the mass of our Sun take a different course, fusing carbon, oxygen, and other elements before their final collapse to a neutron star or black hole. The stars within these extremes will, however, form white dwarfs. But why don't these stars continue their collapse? If white dwarfs cannot generate energy through nuclear fusion, what supports them against their own gravity?

Because of the tremendous pressure to which it is subjected, the matter constituting a white dwarf develops some exotic properties. It is packed together so tightly that all its electrons are torn from their orbits around nuclei. The result is a star consisting of bare atomic nuclei immersed in a sea of electrons. White dwarfs manage to prevent gravitational collapse with a pressure exerted by its electrons — a pressure that has nothing to do with temperature. The pressure from these tightly packed electrons is called *degeneracy pressure*.

The magic of degeneracy pressure comes from the physical properties of electrons combined with the very high density of white dwarfs. In an ordinary gas, such as air or the gas at the Sun's center, atoms are so far apart that their size is much smaller than the average distance between them. They fly freely about, exerting pressure by bouncing off other particles. In a degenerate gas, however, electrons are squeezed together like tennis balls packed tightly in a box. If you tried to compress a gas with degenerate electrons, you would have to supply each electron with more energy as you forced it to occupy a smaller volume. It would be like packing the box of tennis balls more tightly: the only way you could do this would be by squeezing each one.

Electrons act the same way. They resist being squeezed together, demanding more and more energy as they are compacted. In the case of white dwarfs, the compressive force is gravity. Since the white dwarf has a finite mass, its gravity can exert only a limited compressive force. Once the star's gravity squeezes the electrons as close together as it can, there is no additional force available to compact the electrons further, so the collapse halts.

The critical aspect of a white dwarf's degeneracy pressure is that it has absolutely nothing to do with heat or temperature. The electrons simply resist being packed together. A white dwarf slowly cools off as the nuclei within it lose energy and slow down, but the pressure from its electrons remain. Degeneracy pressure acts like a

barrier, forever preventing a white dwarf from collapsing completely.

In our everyday world, the more massive an object is, the greater its size. For example, a 15-kilogram block of lead is bigger than a 10-kilogram block. This rule also holds true for normal stars — those still fusing hydrogen in their cores. For example, Sirius A contains more than twice the mass of the Sun, and it is also 1.8 times larger. White dwarfs, however, are composed of matter under peculiar and exotic conditions. They do not follow this rule.

To see how the radius of a white dwarf changes with mass, let's perform a thought experiment. Imagine a white dwarf of a certain size and mass. Then increase its mass a bit, perhaps by dumping some degenerate matter onto its surface (very carefully!). Now the white dwarf is a little more massive than before. But did the radius of the white dwarf increase or decrease? The matter we added was degenerate — extremely dense. By dumping that material onto the white dwarf, we forced a relatively large increase in the star's mass with only a small increase in its volume. The added mass increases the gravitational field of the white dwarf and compresses its electrons further, packing them more closely than before the mass was added. The decrease in the star's volume due to the extra gravitational compression far outranks any volume increase from the added matter. Weird as it seems, the more massive the white dwarf, the *smaller* its size.

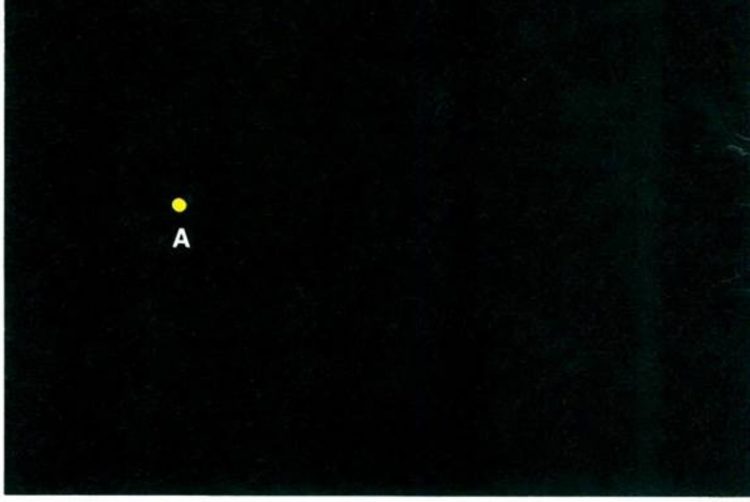
Electron degeneracy pressure, however, does have limitations. A star that leaves a remnant of more than 1.4 solar masses cannot stabilize itself as a white dwarf. In theory, this upper limit to white dwarf masses, called the *Chandrasekhar limit*, can be raised slightly by rotation. However, most known white dwarfs do not rotate fast enough for this side-effect to be significant.

Most of the stars in the Galaxy contain less than three solar masses of material. Consequently, most of the Milky Way's suns are destined to end their lives as white dwarfs. With no energy sources available, isolated white dwarfs can only radiate away the remnant heat of their youth into the deep cold of space. After many billions of years, only a dark, cooled-off cinder remains — the black corpse of a once energetic star.

If a star leaves a remnant more massive than 1.4 Suns at the end of its life, electron degeneracy pressure will not be strong enough to prevent further collapse. Here the electrons collide so violently with the nuclei around them that they combine with protons in the star's nucleus to form neutrons. The collapse proceeds until the remnant is entirely composed of densely packed neutrons. This is a neutron star.

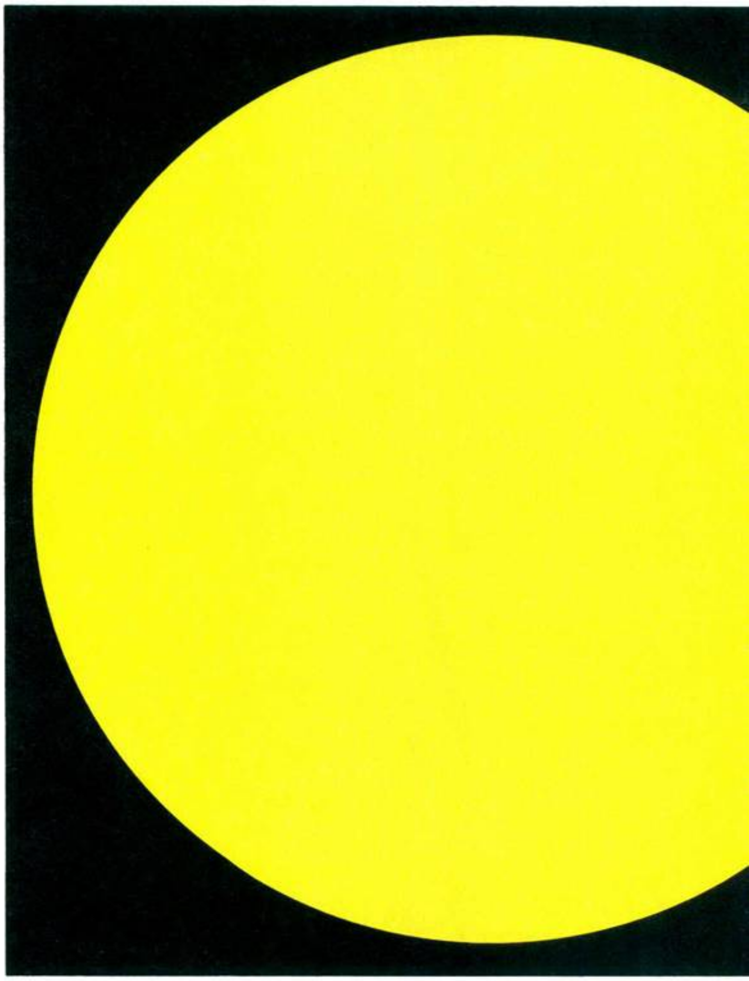
The collapse of a neutron star is halted by neutron degeneracy pressure, a mechanism very similar to the pressure supporting a white dwarf. Neutron degeneracy pressure can support collapsing stars containing up to three solar masses. If a star leaves a remnant heavier than

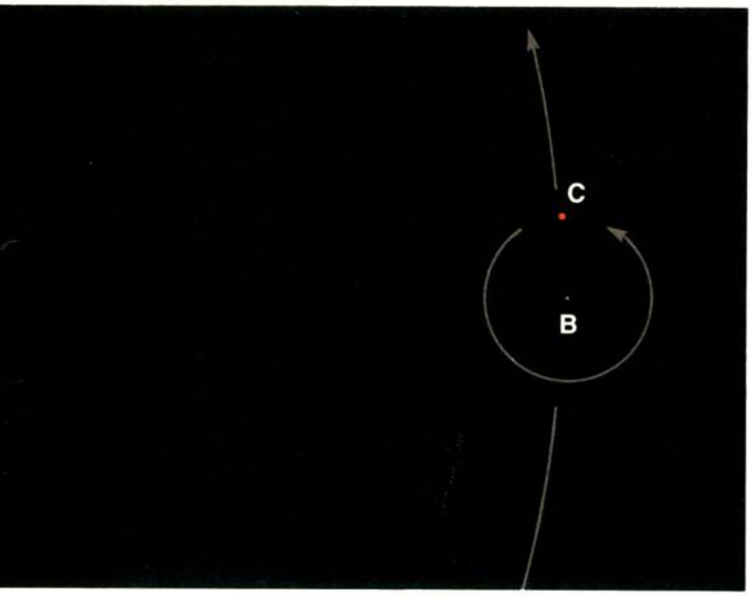
The 40 Eridani System

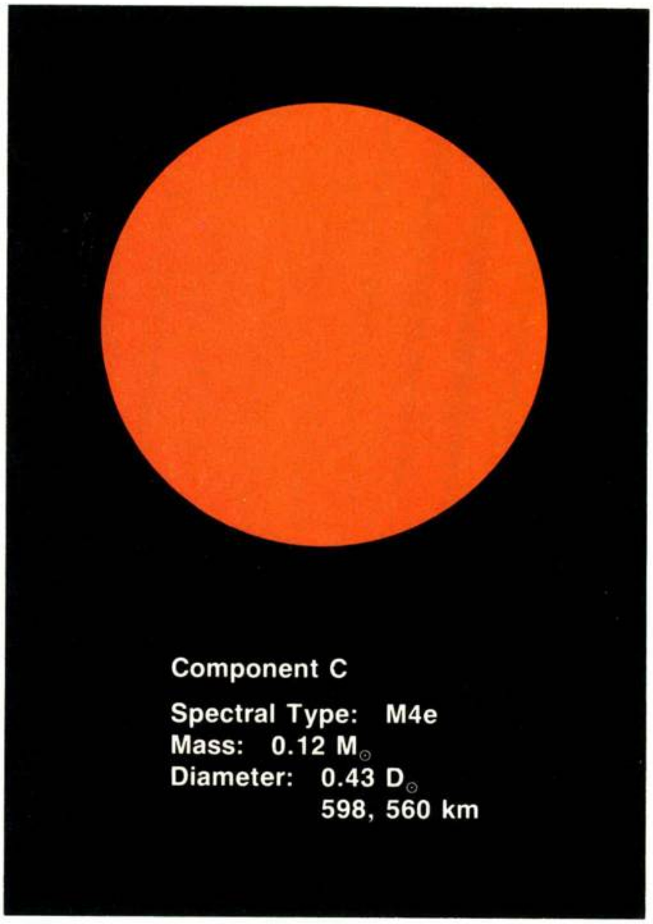


Component B

Spectral Type: DA
Mass: 0.45 $M_\odot$ (solar mass)
Diameter: 0.013 $D_\odot$
18,000 km
Luminosity: 0.0027 $L_\odot$

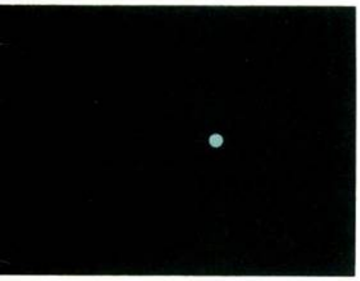


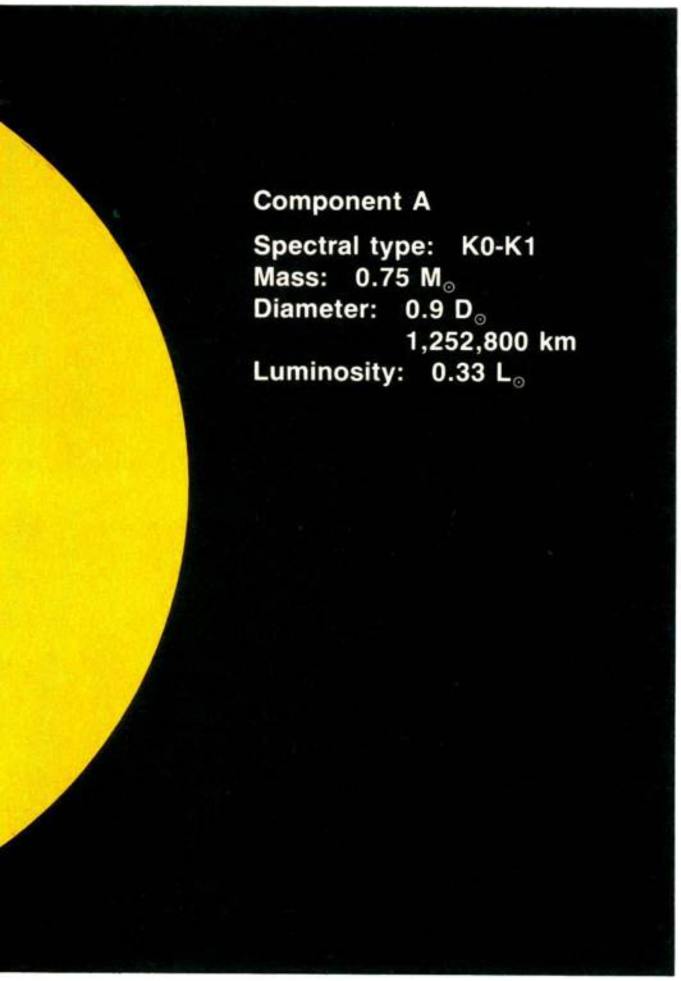




Component C

Spectral Type: M4e
Mass: 0.12 $M_\odot$
Diameter: 0.43 $D_\odot$
598, 560 km





Component A

Spectral type: K0-K1
Mass: 0.75 $M_\odot$
Diameter: 0.9 $D_\odot$
1,252,800 km
Luminosity: 0.33 $L_\odot$

this, the collapse cannot be halted at all and a black hole results. Neutron stars and black holes, however, form in a very different manner than white dwarfs. They are the result of a cataclysmic demise of very massive stars. They are the products of exploded stars, of supernovae.

A white dwarf can take a special route in its evolution if it happens to be one member of a binary system. Binary and other multiple star systems are quite common in the Galaxy. Of the 62 nearest stars, 28 are members of multiple-star systems. Astronomers estimate that only half of all stars in the Galaxy roam through it alone.

Some binary systems have large orbits, keeping their members far apart. In these cases, each star lives out its life relatively oblivious to its companion. But in many other instances, the orbits are small and tight — the individual stars quite close together. In fact, some systems have such small orbits that the surfaces of the two stars actually touch! (See "Contact Binaries: Stars That Touch," ASTRONOMY, December 1982.) When stars are so close together, the evolution of one star can dramatically affect that of its companion. Of the 62 nearest stars, six are white dwarfs, and four of these are in multiple star systems. How can a stellar companion affect the evolution of a white dwarf?

The normal star of a binary system can transfer matter to its shrunken white-dwarf companion. The dwarf draws gas from the outer layers of its stellar neighbor, and this material accumulates on the tiny star's surface. Because the gas is removed from the surface of the normal star, it is rich in fresh, unfused hydrogen. The gas accumulates on the surface of the white dwarf, forming a layer of unprocessed fuel. As the layer deepens, its pressure and temperature steadily increase, and soon the gas becomes so hot that hydrogen explosively fuses into helium on the white dwarf's surface.

As thermonuclear fires rage across the surface, the detonation blows material from the white dwarf, creating a shell of gas that expands radially away from the star. The explosion increases the star's brightness by as much as 100,000 times. This sudden increase in the brightness of a star is called a *nova*. To the ancients who witnessed such an event, it seemed as though a new star had appeared in the heavens ("nova" is Latin for "new"). As the ejected shell grows larger and less dense, it becomes transparent and the nova fades.

As spectacular and energetic as the nova explosion seems, the white dwarf and its companion are hardly affected. Mass transfer quickly resumes, again building a layer of hydrogen fuel and setting the stage for another blast in the future. The time between outbursts depends on how fast hydrogen accumulates on the white dwarf; it could take anywhere from several weeks to many decades. The eruptions from systems that undergo frequent nova episodes are not as energetic as those from systems that take a long time between outbursts. Systems that erupt frequently are called *dwarf novae*. The most

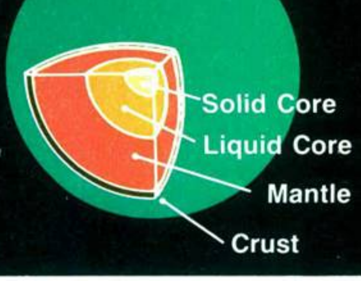
Earth
40 Eridani B

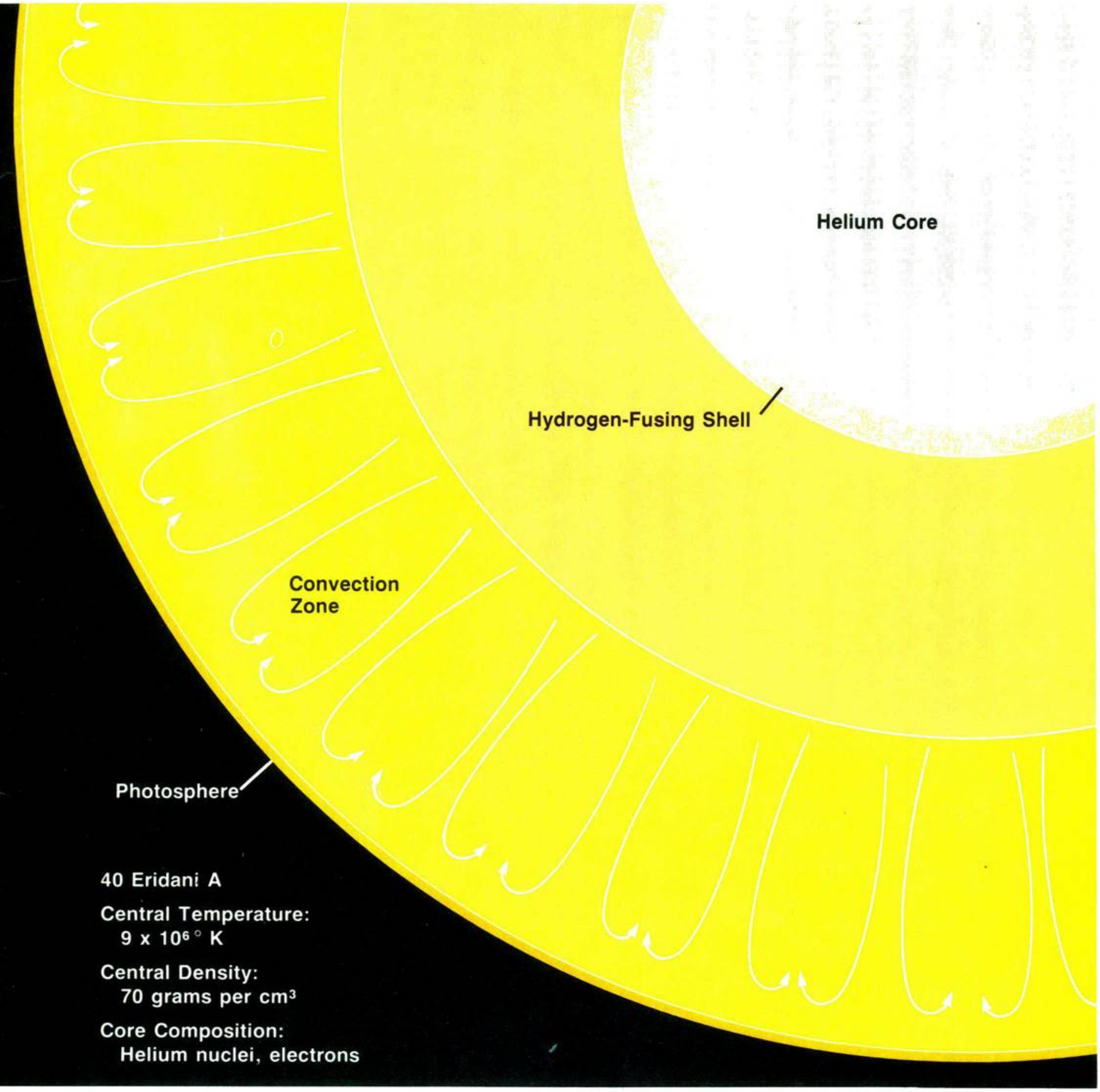
Earth

Central Temperature:
4000° to 5000° K

Central Density:
10 grams per cm³

Core Composition:
Solid and liquid iron/nickel



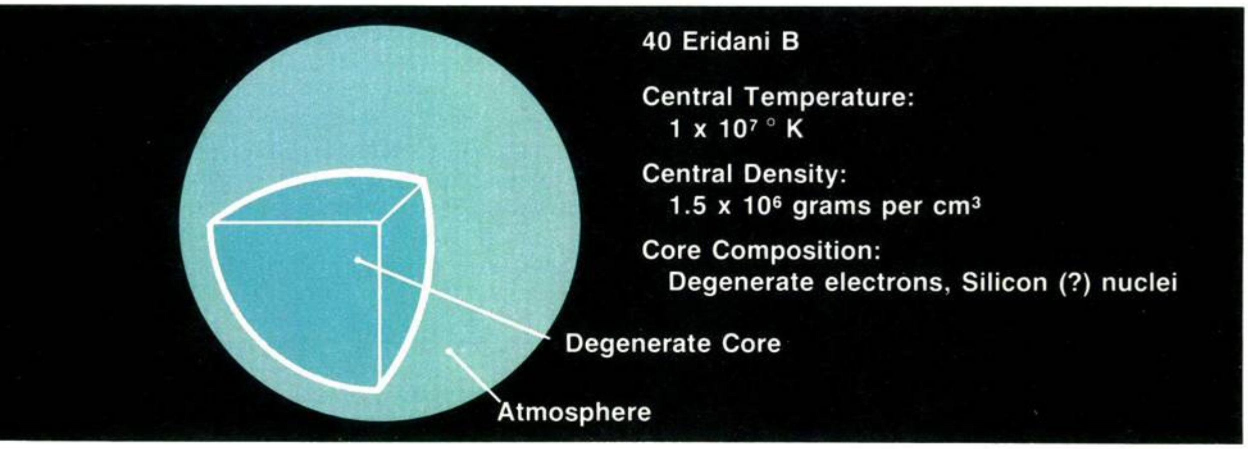

Helium Core
Hydrogen-Fusing Shell
Convection Zone
Photosphere

40 Eridani A

Central Temperature:
9×10^{6} ° K

Central Density:
70 grams per cm^3

Core Composition:
Helium nuclei, electrons

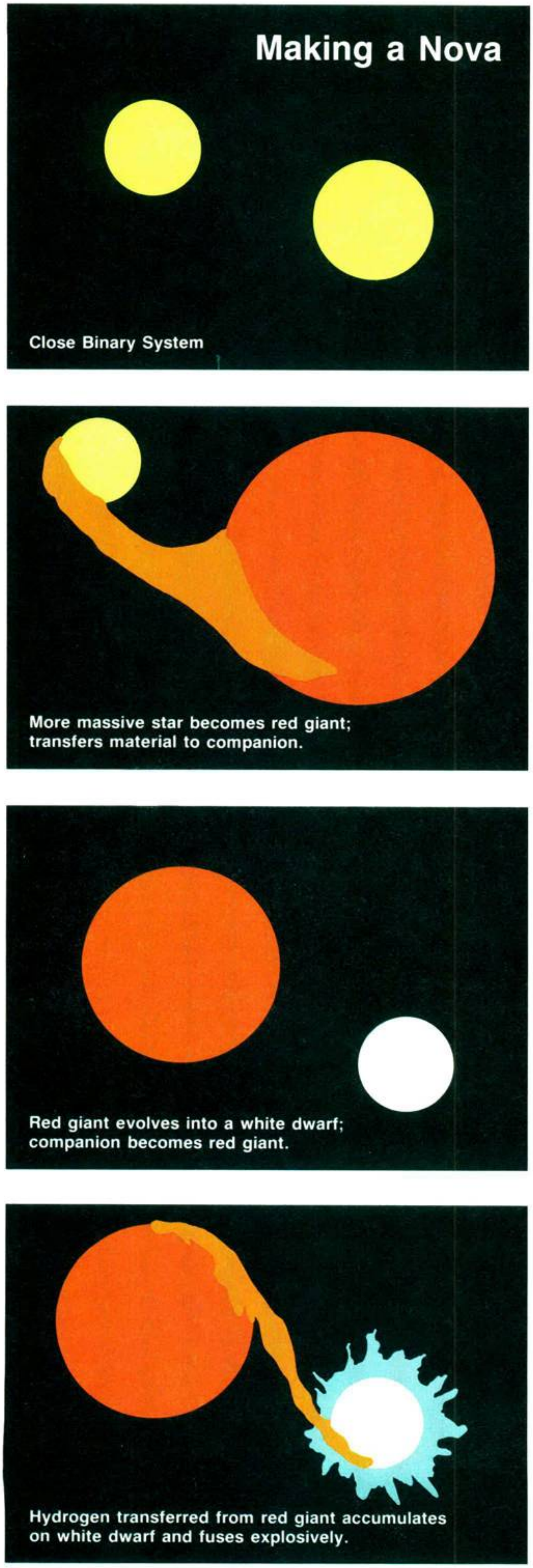

Degenerate Core
Atmosphere

40 Eridani B

Central Temperature:
1×10^{7} ° K

Central Density:
1.5×10^{6} grams per cm^3

Core Composition:
Degenerate electrons, Silicon (?) nuclei



Making a Nova

Close Binary System

More massive star becomes red giant; transfers material to companion.

Red giant evolves into a white dwarf; companion becomes red giant.

Hydrogen transferred from red giant accumulates on white dwarf and fuses explosively.

active dwarf novae have outbursts every two weeks, doubling or quadrupling the star's brightness. When the mass transfer rate is slower, eruptions may occur every few decades; such stars are called *recurrent novae*. Full-fledged novae do not ordinarily explode more often than about once every century.

Supernovae can release far more energy than a nova outburst, yet some astrophysicists have suggested a similar mechanism. One of the most successful models uses a white dwarf made out of carbon and oxygen. If the rate of material transferred to the white dwarf is very high, the accumulated hydrogen will quietly fuse into helium — it won't explode. As the temperature and pressure increase, the helium too will fuse, forming a carbon and oxygen "ash" that settles onto the dwarf's surface. Gradually, the mass of the dwarf increases.

But as its mass approaches the Chandrasekhar limit, the dwarf begins fusing carbon nuclei. The temperature of the dwarf increases, but it cannot stabilize itself — remember, the pressure from its degenerate gas doesn't increase with greater temperature. As the star's interior heats up, the carbon fuses at a faster rate, increasing the temperature still further. When the white dwarf's internal temperature reaches about four *billion* degrees Kelvin, it loses its degeneracy and expands. The expansion decreases the star's density — carbon burning halts less than a second after it started. But the white dwarf, now expanding at 10,000 kilometers per second, is destroyed.

White dwarfs are truly fantastic stars. Soon after their discovery, an unbelieving astronomical community could not make sense of an object with the mass of the Sun packed into a sphere the size of the Earth. What kind of star has a density a million times greater than solid rock? The English astrophysicist Sir Arthur Stanley Eddington, described his feelings in his book *Stars and Atoms*:

> *The message of the Companion of Sirius, when it was decoded, ran: "I am composed of material 3000 times denser than anything you have ever come across; a ton of my material would be a little nugget that you could put in a matchbox." What reply can one make to such a message? The reply that most of us made in 1914 was — "Shut up. Don't talk nonsense."*

Over the intervening years, white dwarfs have yielded their secrets, but only under intense scrutiny. Tiny stars harder than diamond, binary stars trading mass, and cataclysmic nova and supernova blasts are all part of the tales that white dwarfs tell. And yet the amazing complexity of white dwarf stars may hold more surprises in the years ahead.

Anthony J. Nicastro, an assistant professor of physics at Bucknell University, has worked on theoretical models of white dwarfs. His last article for ASTRONOMY, "Flare Stars," appeared in June 1981.

Those Amazing White Dwarfs

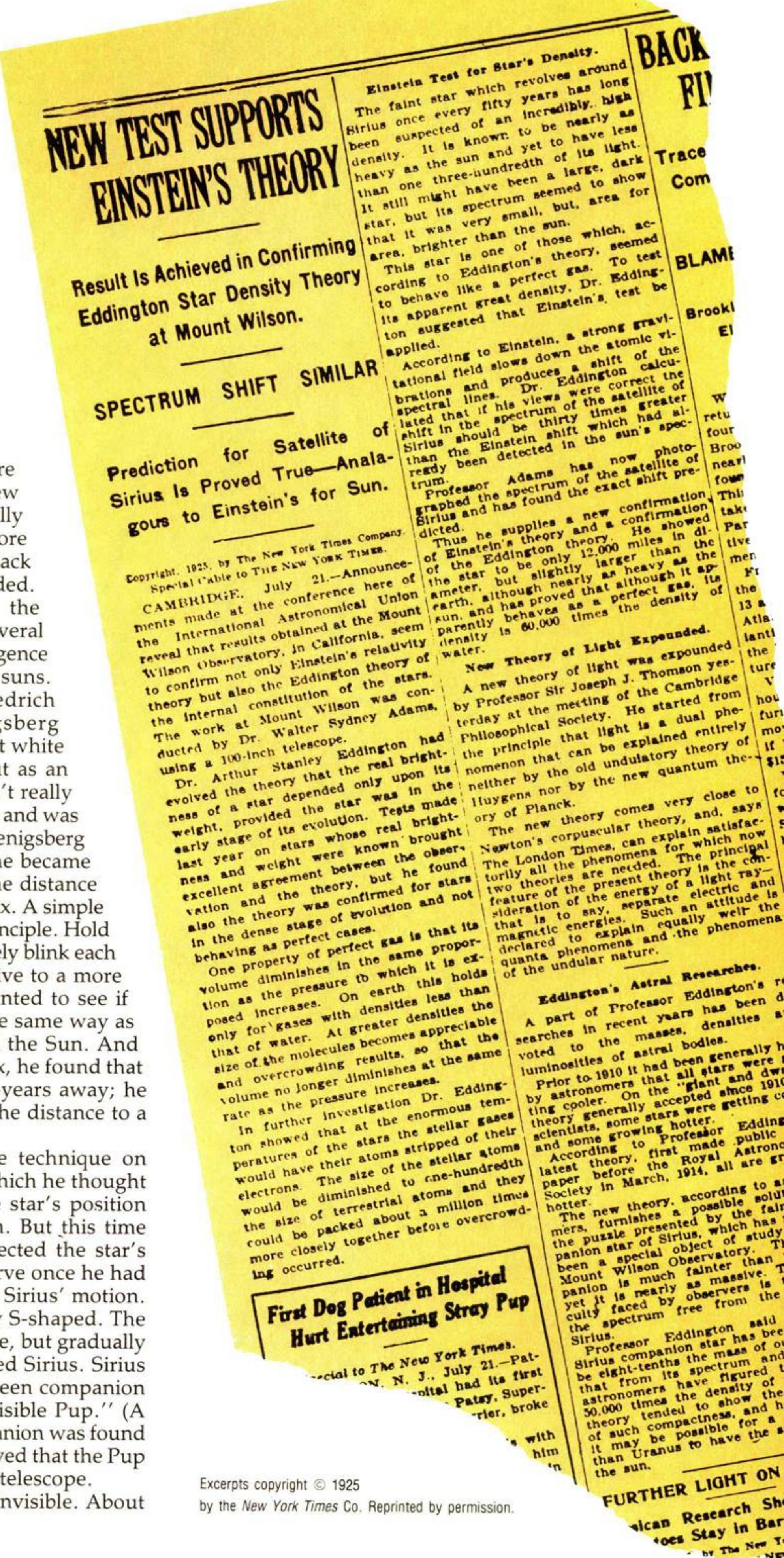
by Barry Parker

At one time white dwarfs were thought to be so exotic that few astronomers believed they really existed. Then along came even more exotic objects, like pulsars and black holes, and interest in white dwarfs faded. They became the neglected sister, the Cinderella of stellar fairy tales. But several recent discoveries have created a resurgence of interest in these tiny, superdense suns.

The German astronomer Friedrich Bessel, director of the Koenigsberg Observatory, stumbled across the first white dwarf in 1844. Bessel had started out as an accountant, but found his heart wasn't really in it. He made the switch to astronomy and was a full professor at the University of Koenigsberg by the time he was 26. In the 1830s he became convinced that he could determine the distance to some of the closer stars using parallax. A simple experiment easily demonstrates the principle. Hold a finger up in front of you and alternately blink each eye; your finger seems to move relative to a more distant object, say, a wall. Bessel wanted to see if some of the nearby stars moved in the same way as a result of the Earth's motion around the Sun. And the technique worked — using parallax, he found that the star 61 Cygni was about 11 light-years away; he thus became the first person to find the distance to a star.

Bessel went on to use the same technique on Sirius, the brightest star in the sky, which he thought closeby. He meticulously plotted the star's position night after night, month after month. But this time something was different. Bessel expected the star's path across the sky to be a smooth curve once he had included all the known corrections to Sirius' motion. But it wasn't — the plot was distinctly S-shaped. The odd wobble confused Bessel for a while, but gradually he reasoned that an unseen star orbited Sirius. Sirius is nicknamed the Dog Star, so its unseen companion naturally became known as "the Invisible Pup." (A few years later a similar invisible companion was found orbiting the star Procyon.) Bessel believed that the Pup was simply too faint to see with his telescope.

But the Pup did not long remain invisible. About



NEW TEST SUPPORTS EINSTEIN'S THEORY

Result Is Achieved in Confirming Eddington Star Density Theory at Mount Wilson.

SPECTRUM SHIFT SIMILAR

Prediction for Satellite of Sirius Is Proved True—Analagous to Einstein's for Sun.

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CAMBRIDGE, July 21.—Announcements made at the conference here of the International Astronomical Union reveal that results obtained at the Mount Wilson Observatory, in California, seem to confirm not only Einstein's relativity theory but also the Eddington theory of the internal constitution of the stars. The work at Mount Wilson was conducted by Dr. Walter Sydney Adams, using a 100-inch telescope.

Dr. Arthur Stanley Eddington had evolved the theory that the real brightness of a star depended only upon its weight, provided the star was in the early stage of its evolution. Tests made last year on stars whose real brightness and weight were known brought excellent agreement between the observation and the theory, but he found also the theory was confirmed for stars in the dense stage of evolution and not behaving as perfect cases.

One property of perfect gas is that its volume diminishes in the same proportion as the pressure to which it is exposed increases. On earth this holds only for gases with densities less than that of water. At greater densities the size of the molecules becomes appreciable and overcrowding results, so that the volume no longer diminishes at the same rate as the pressure increases.

In further investigation Dr. Eddington showed that at the enormous temperatures of the stars the stellar gases would have their atoms stripped of their electrons. The size of the stellar atoms would be diminished to one-hundredth the size of terrestrial atoms and they could be packed about a million times more closely together before overcrowding occurred.

Einstein Test for Star's Density.

The faint star which revolves around Sirius once every fifty years has long been suspected of an incredibly high density. It is known to be nearly as heavy as the sun and yet to have less than one three-hundredth of its light. It still might have been a large, dark star, but its spectrum seemed to show that it was very small, but, area for area, brighter than the sun.

This star is one of those which, according to Eddington's theory, seemed to behave like a perfect gas. To test its apparent great density, Dr. Eddington suggested that Einstein's test be applied.

According to Einstein, a strong gravitational field slows down the atomic vibrations and produces a shift of the spectral lines. Dr. Eddington calculated that if his views were correct the shift in the spectrum of the satellite of Sirius should be thirty times greater than the Einstein shift which had already been detected in the sun's spectrum.

Professor Adams has now photographed the spectrum of the satellite of Sirius and has found the exact shift predicted.

Thus he supplies a new confirmation of Einstein's theory and a confirmation of the Eddington theory. He showed the star to be only 12,000 miles in diameter, but slightly larger than the earth, although nearly as heavy as the sun, and has proved that although it apparently behaves as a perfect gas, its density is 60,000 times the density of water.

New Theory of Light Expounded.

A new theory of light was expounded by Professor Sir Joseph J. Thomson yesterday at the meeting of the Cambridge Philosophical Society. He started from the principle that light is a dual phenomenon that can be explained entirely neither by the old undulatory theory of Huygens nor by the new quantum theory of Planck.

The new theory comes very close to Newton's corpuscular theory, and, says The London Times, can explain satisfactorily all the phenomena for which now two theories are needed. The principal feature of the present theory is the consideration of the energy of a light ray—that is to say, separate electric and magnetic energies. Such an attitude is declared to explain equally well the quanta phenomena and the phenomena of the undular nature.

Eddington's Astral Researches.

A part of Professor Eddington's re
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scientists, some stars were getting co
and some growing hotter.
According to Professor Eddin
latest theory, first made public
paper before the Royal Astron
Society in March, 1914, all are gr
hotter.
The new theory, according to a
mers, furnishes a possible solu
the puzzle presented by the fain
panion star of Sirius, which has
been a special object of study
Mount Wilson Observatory. Th
panion is much fainter than
yet it is nearly as massive. T
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Professor Eddington said
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FURTHER LIGHT ON
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First Dog Patient in Hospital Hurt Entertaining Stray Pup

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N. N. J., July 21.—Pat-
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20 years after Bessel's discovery, the noted American lens-maker Alvan Clark decided to test a telescope he had just completed. He turned it toward Sirius — and what he saw probably made him think there was a flaw in the telescope. Off to the side of Sirius, almost lost in its glow, was a barely perceptible point of light. Clark examined the images of other stars, though, and found that his telescope was working fine. He was actually seeing Bessel's "Invisible Pup," only it wasn't particularly faint, as stars go. It was difficult to see only because of the overwhelming glare from Sirius.

There were even bigger surprises to come. What was the object? It was dim, yet it shone white, like a small star. From the wobble in the motion of Sirius, Bessel could calculate its mass — half that of Sirius itself! The Pup was certainly no planet. Astronomers puzzled over the object but learned nothing further about it for many years. Finally, in 1915, Walter Adams of Mt. Wilson Observatory accomplished the difficult task of passing the Pup's light through a spectroscope. To his amazement, the spectrum indicated an intensely hot surface, almost as hot as that of Sirius. From its temperature and brightness, astronomers calculated that the Pup (now known as Sirius B) was not much larger than Earth. But its mass was indeed half that of Sirius, indicating that its matter was incredibly compressed — a cubic inch would weigh several tons! Scientists had never encountered densities this high, and many astronomers doubted the results. After all, *nothing* could be that dense.

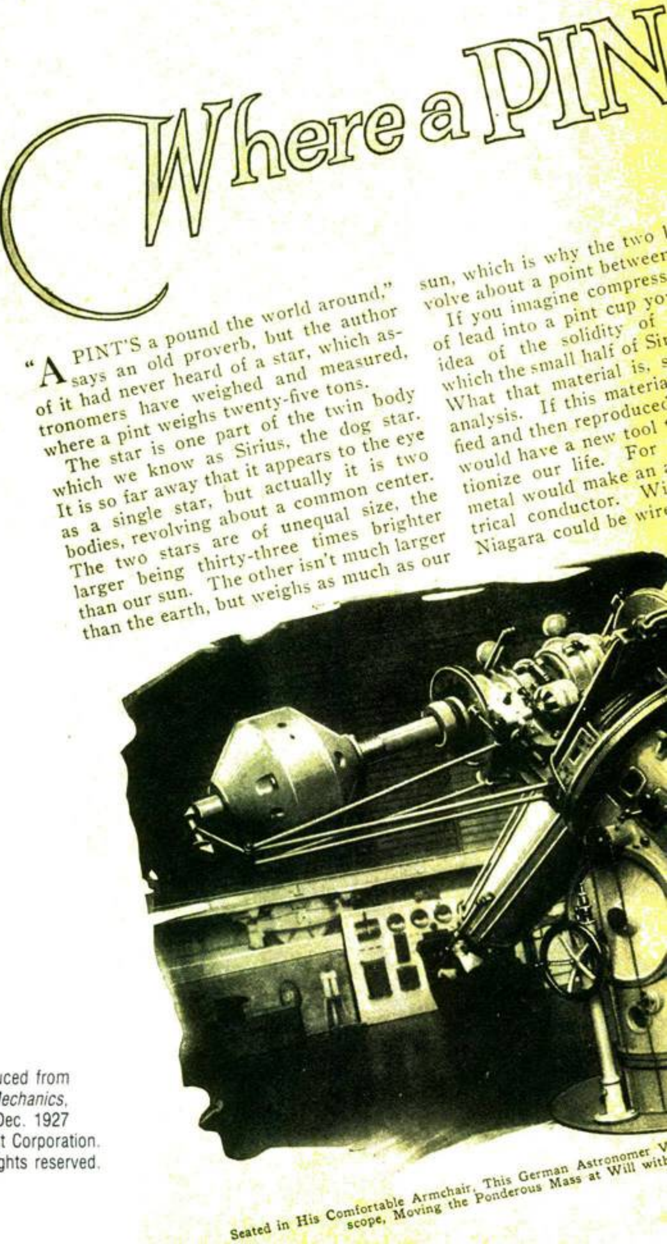
In 1925, Arthur Eddington of Cambridge University in England suggested to Adams that he carefully examine the spectral lines of Sirius B. According to Einstein's General Theory of Relativity, published a decade earlier, each spectral line should be shifted slightly toward the red end of the spectrum if the star's density were indeed as great as calculations indicated. Photons lose energy as they struggle to escape the gravitational field of the star. In ordinary stars the effect is negligible, but, according to the calculations, Sirius B held a stellar mass of material in a ball only slightly larger than the Earth. If this were true, the gravitational force at the star's surface would be 840 times stronger than that at the surface of the Sun. The "tired photon" effect of relativity would be significant.

Adams measured the lines and — sure enough — they were shifted by the predicted amount. This convinced most of the skeptics that Sirius B was indeed small and very dense. But there was now a further problem. During the 1920s Eddington had developed a theory of stellar interiors showing that a star was a ball of gas held in equilibrium by two equal and opposite forces. The powerful gravitational field of a star pulled its constituent gas inward while its high internal temperature simultaneously pushed the gas outward. White dwarfs like Sirius B didn't fit into Eddington's theory — they violated the pressure-temperature relation.

The big breakthrough came in 1926, when Ralph Fowler of Cambridge University published a paper showing that classical physics did not apply to white dwarfs; Eddington's theory was a classical theory. Fowler found that only the new quantum theory, coupled with statistics, could explain the strange white dwarfs. The pressure that supported the star against gravitational collapse didn't come from its high temperature, Fowler claimed. Instead, there was another pressure, which he called *degenerate pressure*. According to his calculations, the pressure from the degenerate gas within Sirius B was sufficient to stop the star from collapsing in on itself.

But what is degenerate pressure? By the early 1920s, scientists had realized that the major constituent of an atom was empty space. If the nucleus of a hydrogen atom was, for example, a small sphere the size of a marble, the electron in orbit around it would lie almost a quarter of a mile away. An atom is 10,000 times larger than its nucleus — more than 99 percent of an atom's volume contains empty space! Sure, it's true that when you touch, say, a table, your fingers don't penetrate it — it feels solid. The shell of electrons in the outermost part of the table's atoms repel those in your hand, creating the impression of solidity. But between these electrons and the nuclei of the table's atoms, there is a lot of space.

In addition, the high temperature inside a star ionizes its constituent gas, ripping away electrons from nuclei. The material inside a star is, in effect, a hot, turbulent — but not very dense — sea of protons (hydrogen nuclei) and electrons. The hotter the gas,



Where a PIN

"A PINT'S a pound the world around," says an old proverb, but the author of it had never heard of a star, which astronomers have weighed and measured, where a pint weighs twenty-five tons.

The star is one part of the twin body which we know as Sirius, the dog star. It is so far away that it appears to the eye as a single star, but actually it is two bodies, revolving about a common center. The two stars are of unequal size, the larger being thirty-three times brighter than our sun. The other isn't much larger than the earth, but weighs as much as our sun, which is why the two
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Seated in His Comfortable Armchair, This German Astronomer V
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Popular Mechanics,
Dec. 1927

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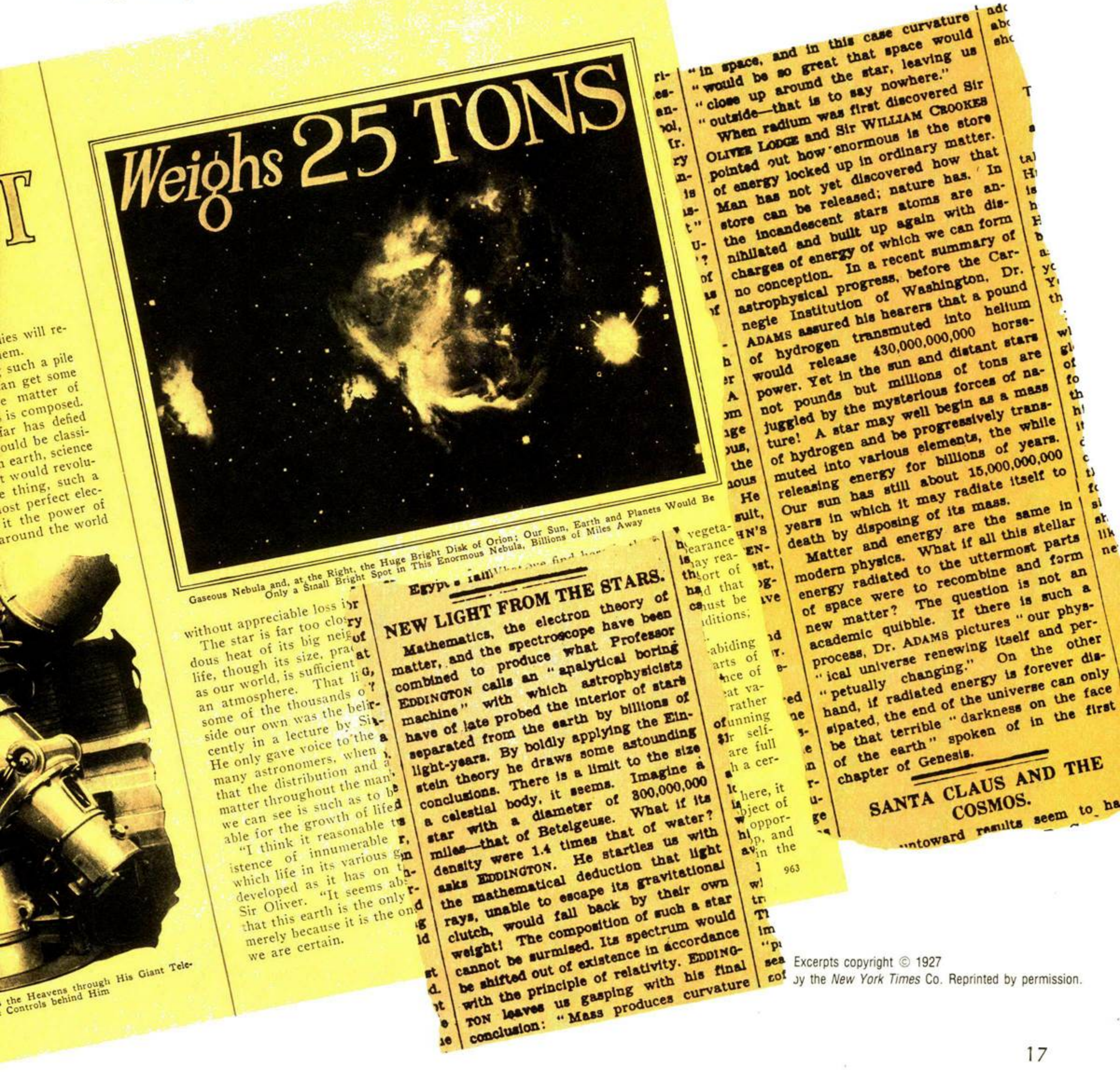
the faster the particles within it move. The pressure that results from the speed of these particles keeps an ordinary star from collapsing in on itself. In a white dwarf, however, gravity has overcome this pressure and squeezed the star into an incredibly small volume — so small that its electrons are, in essence, touching each other. Even at this high density, the star's nuclei remain well separated and electrons move freely among them.

In 1927, physicist Wolfgang Pauli had argued that no two electrons can occupy exactly the same energy state. Electrons abide by the "rules" of quantum mechanics, one of which is called the Pauli Exclusion Principle. Imagine a small box containing only one electron. What happens if you add another electron? The first particle probably already occupies the lowest energy state possible, so the next electron must take a level at a slightly higher energy than that occupied by the first electron. The lowest energy state available to any additional electrons will be higher. This isn't important in a low-density gas, but when the density becomes very high, electrons are forced to occupy high-energy states because the low-energy states are already taken.

In an ordinary gas, the pressure depends on both density and temperature just as Eddington maintained. But the gas pressure inside a white dwarf increases only with density since electrons in degenerate gas cannot revert to lower energy states. The gas pressure, in fact, becomes completely independent of temperature. It's this particular property of this superdense gas that earned it the term "degenerate."



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Gaseous Nebula and, at the Right, the Huge Bright Disk of Orion; Our Sun, Earth and Planets Would Be Only a Small Bright Spot in This Enormous Nebula, Billions of Miles Away

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NEW LIGHT FROM THE STARS.

Mathematics, the electron theory of matter, and the spectroscope have been combined to produce what Professor EDDINGTON calls an "analytical boring machine" with which astrophysicists have of late probed the interior of stars separated from the earth by billions of light-years. By boldly applying the Einstein theory he draws some astounding conclusions. There is a limit to the size a celestial body, it seems. Imagine a star with a diameter of 300,000,000 miles—that of Betelgeuse. What if its density were 1.4 times that of water? asks EDDINGTON. He startles us with the mathematical deduction that light rays, unable to escape its gravitational clutch, would fall back by their own weight! The composition of such a star cannot be surmised. Its spectrum would be shifted out of existence in accordance with the principle of relativity. EDDINGTON leaves us gasping with his final conclusion: "Mass produces curvature "in space, and in this case curvature "would be so great that space would "close up around the star, leaving us "outside—that is to say nowhere."

When radium was first discovered Sir OLIVER LODGE and Sir WILLIAM CROOKES pointed out how enormous is the store of energy locked up in ordinary matter. Man has not yet discovered how that store can be released; nature has. In the incandescent stars atoms are annihilated and built up again with discharges of energy of which we can form no conception. In a recent summary of astrophysical progress, before the Carnegie Institution of Washington, Dr. ADAMS assured his hearers that a pound of hydrogen transmuted into helium would release 430,000,000,000 horsepower. Yet in the sun and distant stars not pounds but millions of tons are juggled by the mysterious forces of nature! A star may well begin as a mass of hydrogen and be progressively transmuted into various elements, the while releasing energy for billions of years. Our sun has still about 15,000,000,000 years in which it may radiate itself to death by disposing of its mass.

Matter and energy are the same in modern physics. What if all this stellar energy radiated to the uttermost parts of space were to recombine and form new matter? The question is not an academic quibble. If there is such a process, Dr. ADAMS pictures "our physical universe renewing itself and perpetually changing." On the other hand, if radiated energy is forever dissipated, the end of the universe can only be that terrible "darkness on the face of the earth" spoken of in the first chapter of Genesis.

SANTA CLAUS AND THE COSMOS.

untoward results seem to ha

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According to Fowler's calculations on stellar evolution, then, gravity pulls the star inward until its electrons become degenerate. The star then stops contracting and remains fixed in size for all time. The white dwarf, it seemed, was the ultimate destiny of the stars.

But was it the destiny of *all* stars? A young Indian physics student named Subrahmanyan Chandrasekhar became interested in Fowler's work. Upon graduation from the University of Madras, he decided he wanted to work under Fowler, packed his bags, and was soon on his way to Cambridge. During the long boat trip, he began looking more critically at Fowler's paper. At the fiercely high temperature inside a white dwarf, the particles would have exceedingly high velocities. So high, according to Chandrasekhar's estimate, that Fowler should have taken the effects of relativity into account — yet he had not.

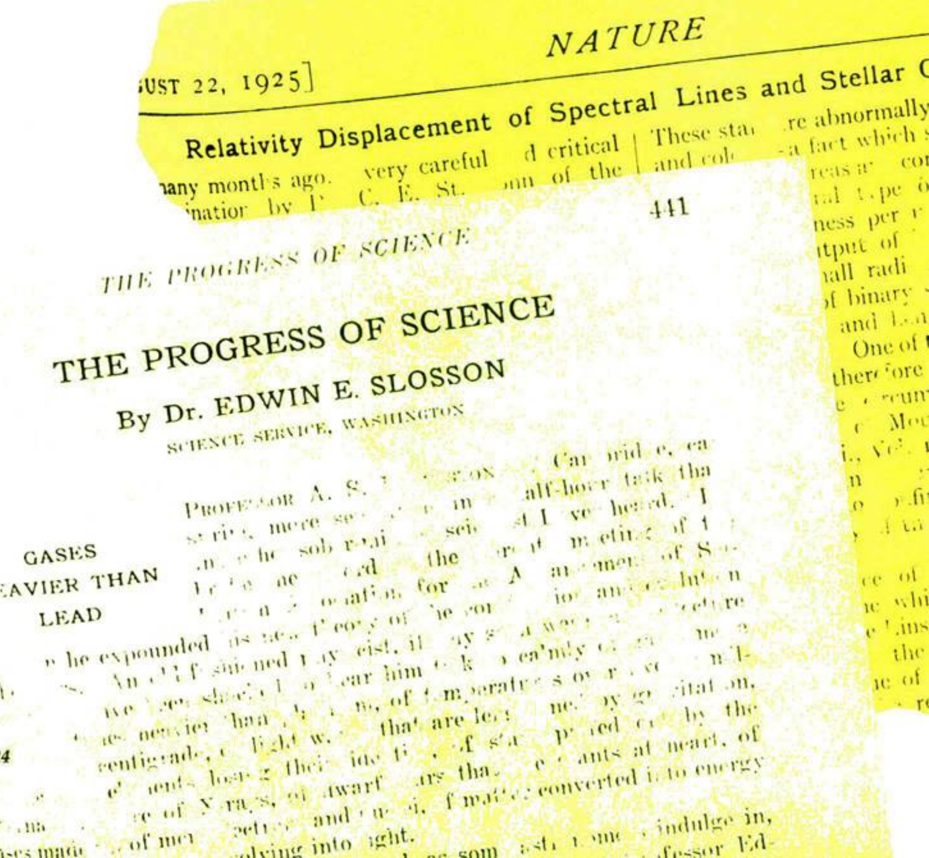
Relativistic effects become very important when particles move at a significant fraction of the speed of light. Chandrasekhar found that these put a limit on the amount of mass that could be squeezed into a stable white dwarf. According to his calculations, only stars with masses less than about 1.4 times that of our Sun could become white dwarfs. Chandrasekhar worked out his ideas and showed them to Fowler when he arrived at Cambridge; Fowler was interested but skeptical. He encouraged Chandrasekhar to develop the idea further and present it to the Royal Astronomical Society.

After considerable work to make sure his ideas were mathematically sound, Chandrasekhar finally presented it. He hoped it would gain immediate acceptance. But much to his surprise, Arthur Eddington presented a counter-paper in which he argued that Chandrasekhar's relativistic degeneracy didn't exist! Chandrasekhar was shocked: Eddington was one of the foremost astronomers in the world and his rejection of the theory could be its death knell. The young astrophysicist hoped he could eventually convince Eddington, but he couldn't; Eddington continued to attack the theory for many years. Although the two remained lifelong friends despite their scientific differences, Eddington's opinion was detrimental, and the scientific community took much longer to accept Chandrasekhar's model than it should have. Logic prevailed in the end, however, and just last year Chandrasekhar was awarded the Nobel Prize for his work.

Although astronomers have found several hundred white dwarfs in our Galaxy, we know this is far short of the actual number. The Milky Way may contain as many as 10 billion white dwarfs, but Earth-based telescopes can detect only those within a few hundred light-years of the Sun. Most white dwarfs are between 7400 and 25,000 kilometers in diameter, making them, on the average, somewhat larger than the Earth — about the size of Uranus. These stars typically have densities 10 million to 100 million times that of water, around 10^7 to 10^8 gm/cm^3, and surface temperatures that range from 5000° to 50,000° K. Of the three best known white dwarfs, two (Sirius B and Procyon B) are in binary systems; the third is a member of the 40 Eridani triple-star system.

The stars that form white dwarfs generally begin their lives with no more than three solar masses of material. Such a star starts out with much the same

> ***"An old-fashioned physicist . . . must have been shocked to hear him [Eddington] talk so calmly of gases more than fifty times heavier than platinum, of temperatures over twenty million degrees centigrade, of light waves that are lengthened by gravitation, of chemical elements losing their identity, of stars puffed out by the internal pressure of X-rays, of dwarf stars that are giants at heart, of gases made up of mere electrons and nuclei, of matter converted into energy and of stars that are dissolving into light."***
>
> *— Edwin E. Slosson, 1924*



NATURE

UST 22, 1925]

Relativity Displacement of Spectral Lines and Stellar

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THE PROGRESS OF SCIENCE

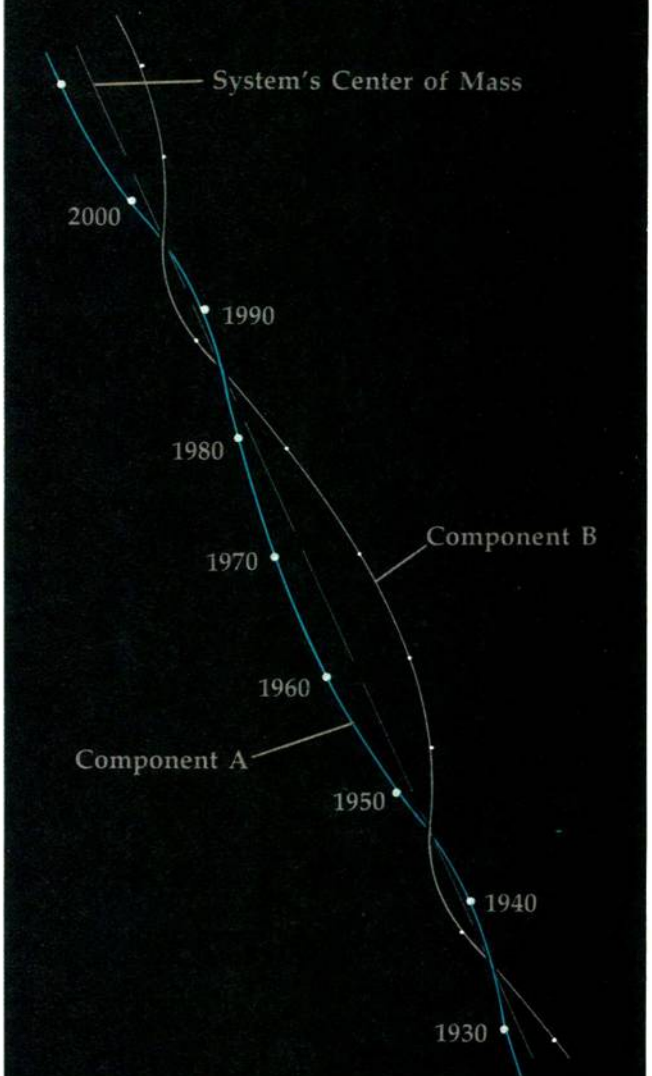
THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

GASES HEAVIER THAN LEAD

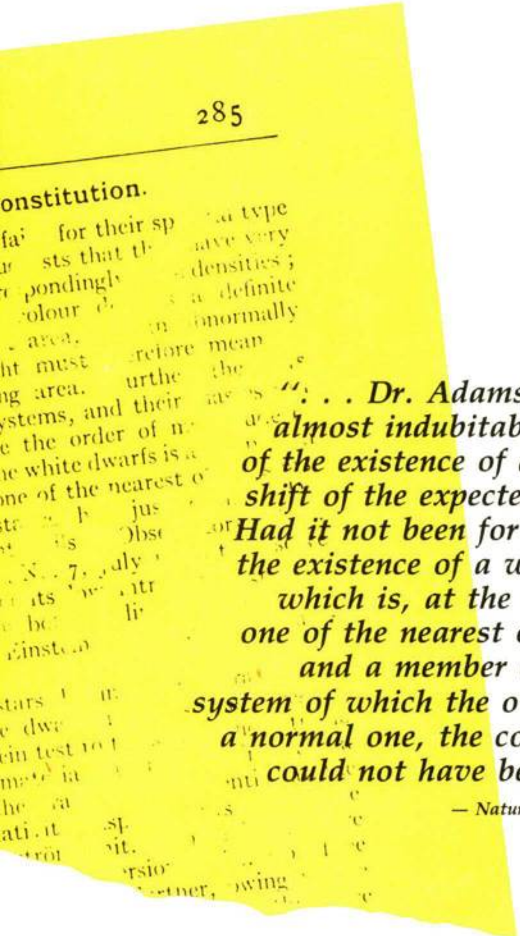
The Motion of Sirius



Friedrich Bessel deduced the presence of the "Invisible Pup" after plotting the motion of Sirius across the sky. The wobble in the star's path represents its motion around the system's center of mass. From this wobble, Bessel realized that a massive object must be grativationally bound to Sirius.

size as our Sun, generating energy by fusing hydrogen nuclei in its core. Helium nuclei, a by-product of these thermonuclear reactions, accumulate at the center of the star's core. When the star has used up the supply of hydrogen in its core, some 10 billion years after its birth, the core contracts and becomes increasingly hotter until finally the helium "ash" in the center ignites. The helium nuclei fuse, releasing energy and forming the nuclei of carbon and oxygen atoms. As before, the heavier nuclei accumulate in the star's center. The star's core at this stage consists of an outer layer that still fuses hydrogen, an inner shell that continues to burn helium, and a dense center made up of carbon and oxygen nuclei. Meanwhile, as the core has contracted, the stellar envelope has now swollen and become cool and red. Little more than a billion years after it ceased fusing hydrogen in its core, the star has become a *red giant*. In a more massive star, the carbon, too, would eventually fuse to release energy and create heavier nuclei. But the temperature never gets high enough for this to happen in stars destined to become white dwarfs.

Red giants tend to eject their outer layers, although no one knows precisely how. Perhaps the tenuous envelope blows off into space, creating a powerful stellar wind. Or perhaps the star becomes unstable and begins to pulsate — throbbing in long, powerful pulses that may be separated by hundreds of thousands of years. Eventually, one of these pulses is strong enough to push off the red giant's outer layers into space.



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onstitution.

". . . Dr. Adams has found almost indubitable evidence of the existence of an Einstein shift of the expected order. . . Had it not been for the fact of the existence of a white dwarf which is, at the same time, one of the nearest of the stars and a member of a binary system of which the other star is a normal one, the confirmation could not have been made."

— Nature, August 22, 1925

However the giant loses its outer envelope of gas, the material moves away, leaving the naked core exposed. The core consists of helium and perhaps a little residual hydrogen surrounding an inner core of carbon and oxygen. This is the first stage of the white dwarf. It now has an exceedingly high surface temperature, perhaps as high as 100,000° K. The dwarf's energetic radiation causes the expanding gaseous shell to glow, creating a *planetary nebula*. With its nuclear furnace now shut down, gravity overcomes the white dwarf, and it shrinks and cools. In about 10,000 years, the shell of glowing gas around the star will have dissipated, and only the white dwarf will remain. It will continue cooling for eons.

The heaviest elements in the dwarf soon begin falling toward its center, and the small amount of remaining hydrogen is squeezed out into the atmosphere. All white dwarfs have atmospheres a few tens of meters thick. Spectroscopic analysis shows that some of them consist almost entirely of hydrogen, a few contain only helium, and some contain a mixture of both gases. In most cases, however, there is no hydrogen inside the white dwarf.

As we mentioned earlier, most of a white dwarf's material is in the degenerate state. Parts of the dwarf that are *not* degenerate include its atmosphere and an outer layer, a region about 40 km thick. The major constituent of this outer region is probably helium.

The degenerate region lies beneath the outer layer and has a constant temperature; it remains approximately the same all the way to the center. The material here is highly compressed due to the tremendous weight of the layers above it. It is able to support them because the Pauli Principle does not allow more than one electron to be squeezed into the same small space.

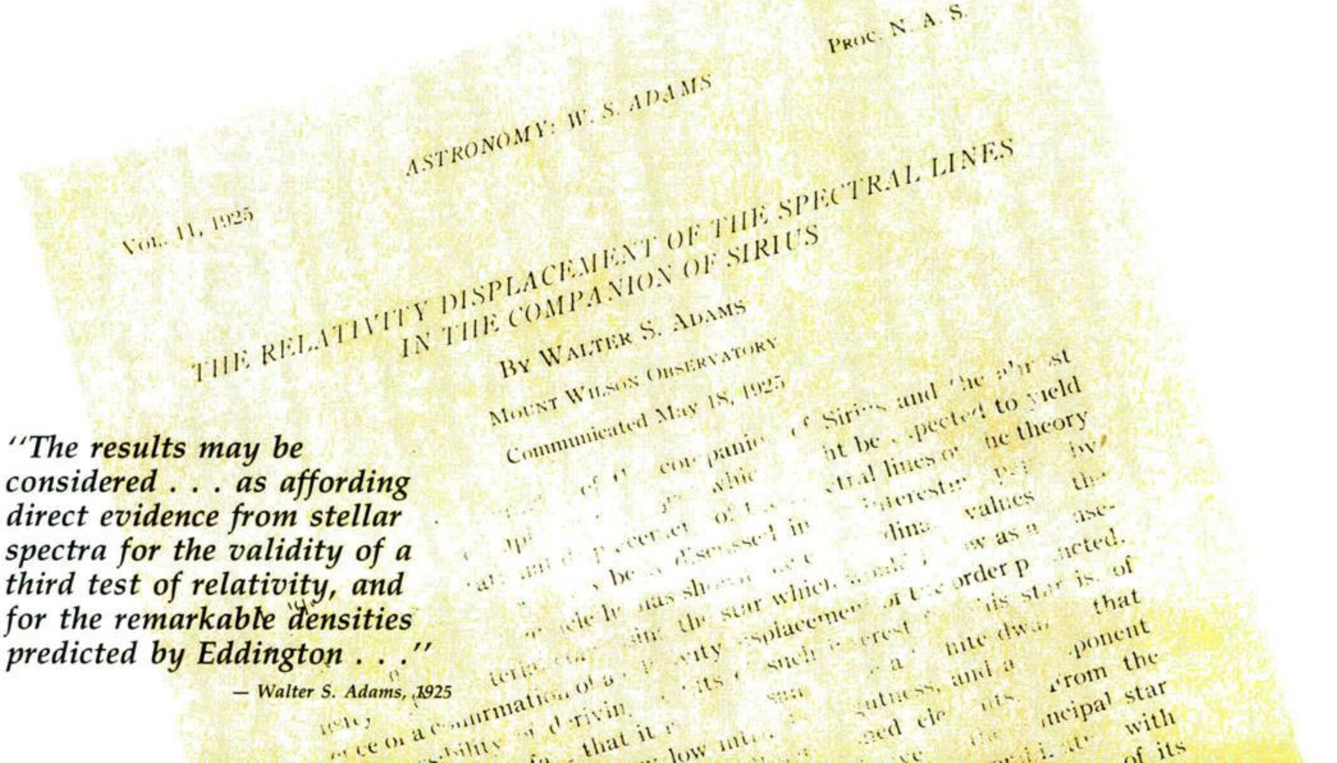
But as we saw earlier, the resulting pressure — the degenerate electron pressure — is only able to support stars with masses less than 1.4 times that of the Sun. There are, of course, many stars more massive than this. What happens to them? Chandrasekhar wondered about this but he did not pursue it. The answer, it turned out, had to await the discovery of *inverse beta decay*. A free neutron — that is, one not bound within an atomic nucleus — decays in about 12 minutes to form a proton and an electron. This process is called beta decay. Inverse beta decay occurs when a proton and an electron join to form a neutron. The high pressure exerted by the collapse of a star greater than 1.4 solar masses squeezes the star's electrons and protons together to form neutrons. Although Chandrasekhar's theory does not apply to neutrons, later calculations showed that there is a neutron degeneracy pressure that keeps the star from collapsing in on itself. The end result, a neutron star, is even more compressed than a white dwarf.

Most white dwarfs exist in a state of stable equilibrium. Nothing much happens to them over billions of years. They just gradually cool off and, after a few tens of billions of years, fade away to become cold, dense, dark objects — black dwarfs. It's unlikely, though, that there are any black dwarfs in our Galaxy — it just isn't old enough. Some white dwarfs, however, are not completely docile — one group, called ZZ Ceti stars, actually fluctuates in brightness. The change is slight, though — between 0.01 and 0.3 magnitude over periods ranging from 2 to 20 minutes. Astronomers aren't sure what causes this variability, but one possibility is that the white dwarfs actually pulsate, slowly increasing and decreasing their size.

Astrophysicists have also found magnetic white dwarfs. In fact, they've paid considerable attention to these magnetic midgets in the last few years. The magnetic fields are very strong, up to 100 million gauss. At a strength of 0.5 gauss, Earth's magnetic field is puny in comparison.

Their intense fields aside, magnetic white dwarfs don't seem structurally different from other white dwarfs. The magnetic field does, however, create one significant difference — it somehow influences the dwarf's atmospheric composition. Of the 16 known magnetic white dwarfs, three have almost pure hydrogen atmospheres and two have nearly pure helium atmospheres; two dwarfs exhibit particularly strange atmospheric spectra that cannot be readily interpreted. How the magnetic field influences atmospheric composition is not well understood at the present time. Ordinary white dwarfs no doubt accrete some hydrogen from interstellar gas. A possible explanation for the peculiar atmospheres of these stars is that their intense magnetic fields may restrict such accretion.

How do magnetic white dwarfs get their strong fields? After all, ordinary stars have relatively weak magnetic fields. To understand, imagine the magnetic field as if it were composed of some number of lines



Vol. 11, 1925

ASTRONOMY: W. S. ADAMS

PROC. N. A. S.

THE RELATIVITY DISPLACEMENT OF THE SPECTRAL LINES IN THE COMPANION OF SIRIUS

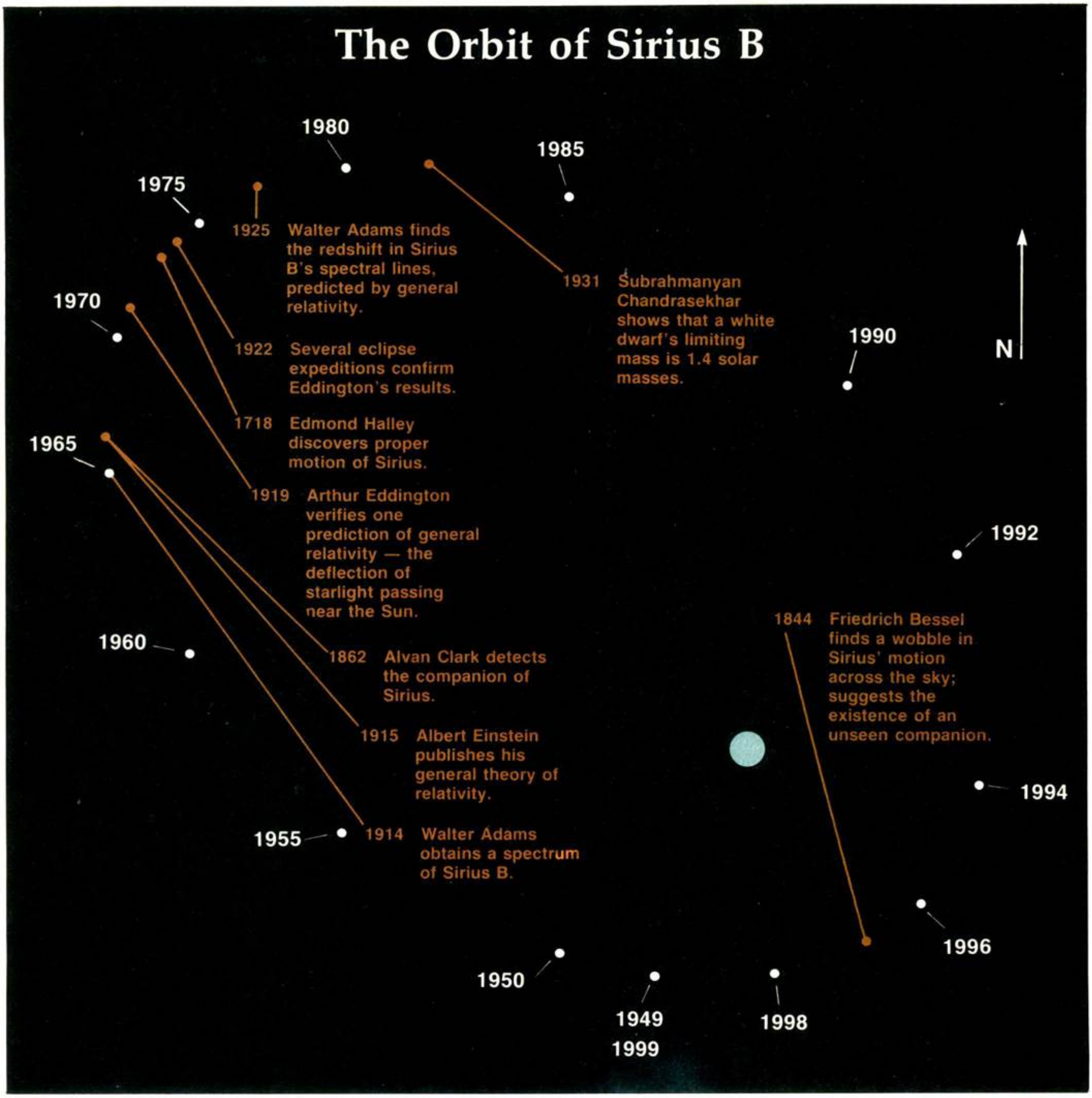
By Walter S. Adams

Mount Wilson Observatory

Communicated May 18, 1925

"The results may be considered . . . as affording direct evidence from stellar spectra for the validity of a third test of relativity, and for the remarkable densities predicted by Eddington . . ."

— Walter S. Adams, 1925



The Orbit of Sirius B

1925 Walter Adams finds the redshift in Sirius B's spectral lines, predicted by general relativity.

1931 Subrahmanyan Chandrasekhar shows that a white dwarf's limiting mass is 1.4 solar masses.

1922 Several eclipse expeditions confirm Eddington's results.

1718 Edmond Halley discovers proper motion of Sirius.

1919 Arthur Eddington verifies one prediction of general relativity — the deflection of starlight passing near the Sun.

1844 Friedrich Bessel finds a wobble in Sirius' motion across the sky; suggests the existence of an unseen companion.

1862 Alvan Clark detects the companion of Sirius.

1915 Albert Einstein publishes his general theory of relativity.

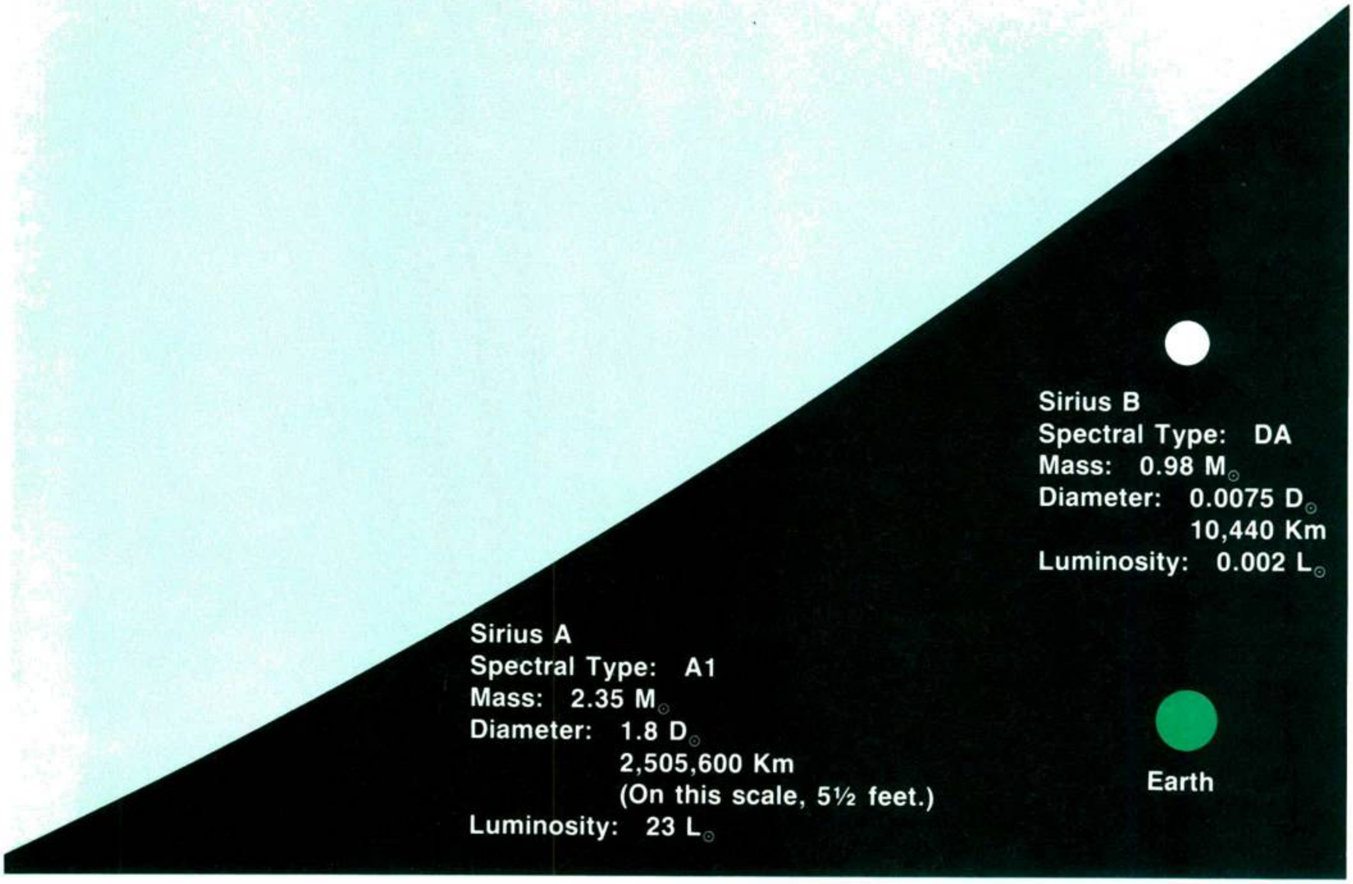
1914 Walter Adams obtains a spectrum of Sirius B.

per unit area emanating from the star. As a star collapses, the number of lines remains constant, but the lines are pushed closer together as the surface area decreases. The surface area of an ordinary star is about a million times greater than that of a white dwarf. Clearly, the increase in the strength of a collapsing star's magnetic field is substantial. But even so, the field of the original star must be pretty strong in order to wind up with a 100-million-gauss white dwarf.

Magnetic fields play a more important role in the evolution of binary white dwarfs. Material lost by a normal star is pulled into orbit around the white dwarf. A thin accretion-disk forms around the star at a temperature of 10,000° K. Gas enters the disk at the outer edge but, due to internal friction, the material loses energy and slowly spirals in toward the white dwarf. Finally, the captured gas rains down on the dwarf's surface.

A magnetized white dwarf creates a different scenario. In these systems, material from the primary does not normally form an accretion disk around the white dwarf. This material is ionized, or electrically charged, and its motion is therefore influenced by the magnetic field. The gas flows easily along magnetic field lines, but is unable to cross them. The gas becomes locked into the magnetic field and flows along the converging field lines, striking the surface at the star's north and south magnetic poles without forming an accretion disk. Astronomers believe that the strong X-ray source AM Herculis is powered by such a process.

In some cases the very presence of an *ordinary* white dwarf in a binary system is a puzzle. Take the Sirius system, comprised of two stars: Sirius A, which has more than twice the mass of our Sun, and Sirius B, which weighs in at about one solar mass. Yet Sirius

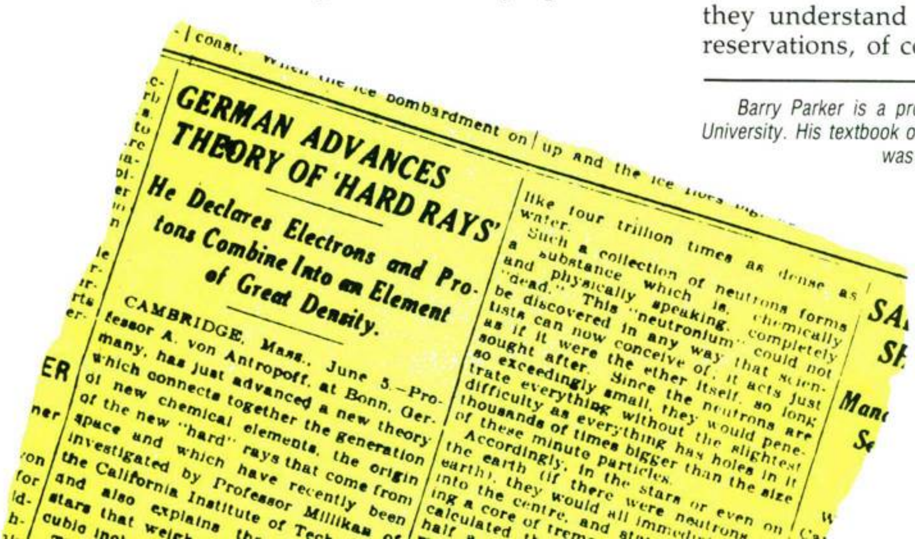


B is a white dwarf, which means that it has gone through its life cycle and is now a dead star, well on its way to the stellar graveyard. Sirius A, on the other hand, is a large blue star, still apparently quite young. But massive stars are supposed to evolve faster than less massive ones. Sirius A should have died long before Sirius B.

Obviously, things must be a little more complicated in binary systems. To see how the system may have evolved, let's begin long before component B became a white dwarf. Astronomers assume that B must have been much more massive than A. B might have held two or three solar masses, while A contained only about one solar mass. B thus evolved faster and soon became a bloated red giant. Eventually it pushed its outer layers — as much as two solar masses — into space, leaving behind a core of about one solar mass, the mass we now observe for Sirius B. Over millions of years, this core slowly cooled to its present temperature of about 5000° K. Most of the material ejected by B dissipated into space, but Sirius A no doubt captured a considerable fraction of it, possibly adding nearly another solar mass to the star. Thus, what we see today is a white dwarf of one solar mass and a rejuvenated blue star with a mass twice that of our Sun.

Astronomers have, in the last few years, learned a considerable amount about white dwarfs. Thanks to Chandrasekhar and Fowler, and a myriad of studies over several decades, astronomers now believe that they understand white dwarfs pretty well — with reservations, of course.

Barry Parker is a professor of physics and astronomy at Idaho State University. His textbook of elementary astronomy, Concepts of the Cosmos, *was recently published by Harcourt Brace Jovanovich.*



GERMAN ADVANCES THEORY OF 'HARD RAYS'

He Declares Electrons and Protons Combine Into an Element of Great Density.

CAMBRIDGE, Mass., June 5.—Professor A. von Antropoff, at Bonn, Germany, has just advanced a new theory which connects together the generation of new chemical elements, the origin of the new "hard" rays that come from space and which have recently been investigated by Professor Millikan of the California Institute of Tech and also explains th stars that weigh cubic inch

like four trillion times as dense as water.

Such a collection of neutrons forms a substance which is, chemically and physically speaking, completely "dead." This "neutronium" could not be discovered in any way that scientists can now conceive of. It acts just as if it were the ether itself, so long sought after. Since the neutrons are so exceedingly small, they would penetrate everything without the slightest difficulty as everything has holes in it thousands of times bigger than the size of these minute particles.

Accordingly, in the stars or even on the earth (if there were neutrons on earth), they would all immedi into the centre, and st ing a core of trem calculated half

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ASTRONOMY Forum

A True Confession

I'm lousy at math.

I consider myself a first-rate amateur astronomer.

No contradiction, no brag. Just fact.

And I'm not being arrogant, so those of you who have your throwing arms cocked had best drop your stones back where they belong. I'm telling it like it is. You don't survive nearly 25 years of amateur astronomy unless you're pretty darn good at it.

So I'm pretty darn good, but I'm lousy at math.

Whenever I read a text on astronomy, I am forced to ignore most of the formulas and all but the simplest of calculations, and *that's* what I hear turns on the professionals and gets their juices flowing. Had it not been for the math, I can assure you that I would have majored in astronomy and not English in college. Ahhh, but a penchant for numbers is a prerequisite for an astronomy degree, and a much-needed tool in the professional field. Without it, a candidate for an astronomy degree is helpless.

Not so in the amateur field. I'm living proof.

Wanna know something else? Now I'm darn glad I majored in English. If I could magically change my major, I wouldn't.

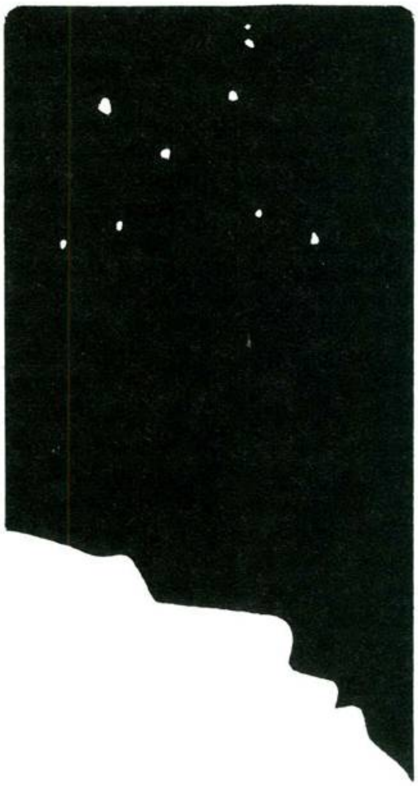
Why? Because I'm right where I want to be right now, doing what I do best: writing about astronomy.

Why am I telling you this?

I know that there are plenty of folks out there who are reluctant to embrace amateur *astronomy*. Maybe even you — you have this fear that you will not be able to hack the science involved. You suspect that your lack of talent in this area will prove to be an insurmountable stumbling block and an embarrassment. Secretly, you dread being given the dunce cap at the star party.

So, you fight the urge to give astronomy a try.

It's a dumb thing to do. Being good at math is not, repeat *not*, a prerequisite for becoming an amateur astronomer. Neither is being scientifically inclined. Neither is having a high intellect.



I correspond with one of the most devoted amateur astronomers I know. Regularly. We exchange written descriptions of deep-sky objects. He happens to use a 4-inch f/15 refractor, and so do I. This so, comparing notes is helpful and enlightening, especially when questionable observations made independently of each other concur. On the average, every page of his lengthy descriptions contains 50 grossly misspelled words. His grammar is atrocious. His sentence structure is always awkward. And yet, his eyes *see*. He's a better observer than I am, and I'm pretty darn good.

My friend never made it past the fifth grade. He cannot divide or multiply. He doesn't know what algebra is. The United States Army didn't want him. Some folks around his town call him the village idiot. He works with a clean-up crew of a construction company for minimum wage, and he saved his hard-earned pennies for six long years so he could buy the telescope of his dreams.

My friend cannot spell the names of the constellations, but he knows them like the backs of his strong hands. He can't read a thermometer, but he can accurately estimate the visual magnitude of a star. He can break bricks with his bare hands, yet he can fine-focus with gentle precision, too. He gets lost immediately amid the simplest technical mumbo-jumbo, but knows his way around the most dimly lit back alleys of the universe.

If he's an idiot, I'm Porky Pig.

If he's not an excellent and gifted amateur astronomer, I'm Porky Pig's mother.

He's been observing with his own telescope for just over four years now. With each of his letters he teaches me something, reveals to me a subtle nuance of a deep-sky object that I had never noticed before. He stays excited about astronomy. He's a dynamo who will not be stopped or even slowed down. His enthusiasm is infectious.

He has never even considered the possibility that he is not intelligent enough to be an amateur astronomer.

"I got good eyes," he told me during his very first look through my telescope nearly 10 years ago.

Amen to that.

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He doesn't read well, either. The few books he has read were checked out of the children's section of his local library, and most of those only confused him. He was forced to learn amateur astronomy by — get this — *observing*! Hours stacked upon hours of staring through the eyepiece of his refractor. Simply that, nothing more. Nothing fancy.

Not once during his years of observing has he had the time to come down with aperture fever. He doesn't even know what it is! Not once has he mentioned the need for a larger telescope, or a variable-speed drive corrector, or an astro-camera, or larger finder, or even a new and improved eyepiece. He's too busy *observing*.

He's satisfied with his 4-inch precision eye, and he gets more out of it than several astronomer friends of mine who have expensive monsters protected by expensive domes and intellects that tease Einstein's. Nobody told my friend that he wasn't smart enough to tackle amateur astronomy, and every clear night the universe tells him that he is. My friend just gets better and better and happier and happier. He observes circles around me. He's taught me more than any textbook.

I owe him.

He opened my eyes when I was still very low about my shortcomings in math. He made me realize that I should not give up on astronomy, but focus my energies elsewhere and make use of what talents I have. You see, I dearly wanted to teach astronomy on the college level. Astronomy was in my blood, and I wanted to infect others. But I was quickly hog-tied with seemingly nowhere to go. If you can't hack the calculus, the degree is an impossible dream. My dream of doing something useful in the field of astronomy almost died. I almost killed it. My special friend saved its life.

"In college," he said, slurring his words, "you teach a lot of people. If you write about astronomy, you can teach a lot more."

So now, you're reading this. Soon I will have a book out.

My dream is alive and kicking.

My special friend taught me something. Will you let him teach you something through me?

If so, maybe — just maybe — you will not let anyone tell you that you are not intelligent enough to pursue amateur astronomy. Maybe you will not let your brain stand in the way of your heart.

Square your shoulders and say, "I can and will observe!"

And maybe — just maybe — this lesson will cause some of you more gifted and experienced amateurs out there to get up off your duffs and share the universe with those less fortunate than you. *Outreach* is the word.

Share your telescope with the mentally retarded.

My special friend is mentally retarded.

The universe doesn't care, and neither does he. They've got each other. And I've got both of them, thank God.

Ken Fulton
Temple, TX

Undesirable Aliens

Is it wise to try to contact extraterrestrials?

It's surprising how seldom this question comes up. Interstellar communication, after all, is hardly a neglected topic — it has already inspired enough academic theorizing to fill several library shelves. But so far astronomers have chiefly investigated the problem of communication technique — the "how" of contacting aliens. A much more fundamental problem — the "why" — has been ignored.

Maybe it's time they, and we, stopped ignoring it and started to give it some hard thought. It's crazy to worry over how you'd do something until you're sure that you ought to be doing it in the first place.

The whole question of trying to contact aliens hinges on what would happen if we succeeded. That, in turn, depends on how the aliens we contacted would behave. Would they be friendly or hostile? Peaceful or warlike? Would they be as carefully altruistic as a 20th-century anthropologist — or as ruthlessly selfish as a 17th-century colonial?

Sometimes, of course, you hear scientists talking so knowledgeably about aliens that you'd think they had just vacationed on Betelgeuse VII. One authority says that they must be peace-loving in order not to have bombed themselves to atoms. Another says they must be more or less like human beings, because natural selection would guarantee it. A third, weirdly, argues that because they have never visited us, it demonstrably follows that they don't even exist!

But if you analyze such notions with any rigor, you'll soon discover that each is scientifically bankrupt — a tissue of random, unsubstantiated assumptions. And how could it be otherwise? Our reliable data on extraterrestrial intelligence aren't exactly plentiful — indeed, unless you believe the nuttier flying-saucer freaks, we have *no* reliable data on extraterrestrial intelligence. In the words of writer Anna Hollin, "All we really know about the aliens is that we know nothing about them at all."

This little homily is worth remembering. Grasp it firmly enough and you find it annihilates most "research" into aliens. Articles masquerading as science turn out to be actually science fiction — and worse, *bad* science fiction, painfully unimaginative. If you want a good idea of what extraterrestrials might truly be like, you'd do better to avoid the astronomers' amateur SF and turn to the real thing. Read about H.G. Wells's Martians, *Star Trek*'s Klingons, Tolkien's hobbits, elves, and orcs. None of these creatures is scientifically impossible and none is too bizarre to be living somewhere in our Galaxy right now.

Though SF's aliens have always been diverse, at any given period they are either mostly nasty or mostly nice. In the 50s, fashion favored malevolent bug-eyed monsters. Nowadays — and for this we can largely thank Steven Spielberg — aliens are as sweet as saccharin and as kindly as Saint Francis. And if this vogue is powerful in the world of science fiction, it's virtually omnipotent in the world of science fact. I've discussed extraterrestrials with literally dozens of astronomers and, without exception, they have been convinced of alien benignity. The Good Extraterrestrial seems as deeply rooted in current scientific mythology as the Good Samaritan is in the Christian.

Sometimes, surprised at this unshakable faith in alien goodwill, I've asked astronomers why they cling to it so tenaciously. Their only answer has been to gaze at me in speechless, wide-eyed bewilderment. Yet this begs the question, for the truth is simple: there is *no reason whatsoever* to suppose that extraterrestrials must necessarily be benevolent. They might well be as lovable as Spielberg's darling E.T., or they might be as malicious as Wells's Martians. Or, like human beings, they may fall somewhere in between. The possibilities are incalculable, and precisely because they are incalculable, we can't rule out any of them — not even the most nightmarish. If some aliens were Spielbergian angels, others might be as implacably hostile as any of the devils in Dante's *Inferno*.

The notion of extraterrestrial devils is terrifying enough, but I've another that's more terrifying still. Anna Hollin said that we know nothing about aliens at all, but if she meant the kind of aliens with whom we might communicate, she was wrong in one detail. If we ever succeeded in

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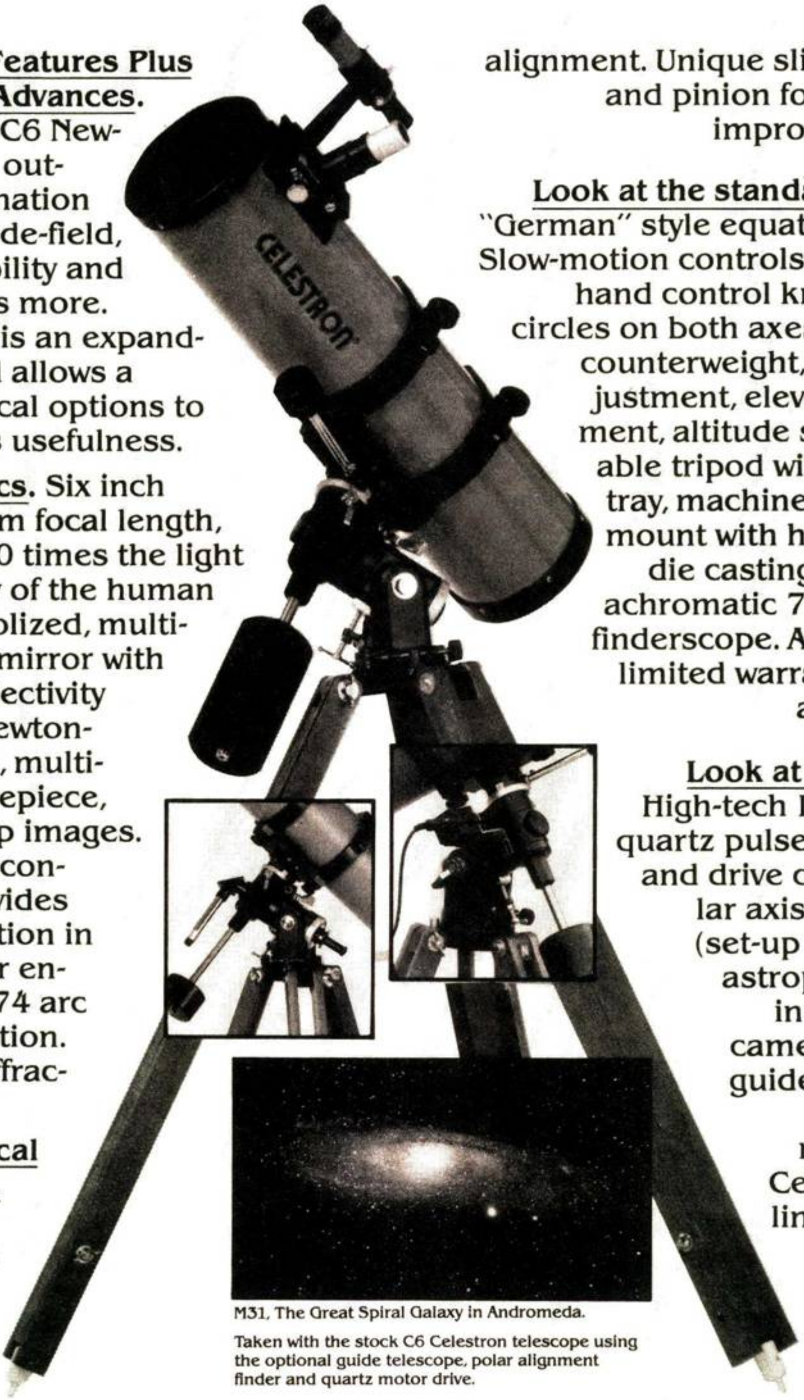

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CELESTRON INTERNATIONAL, P.O. Box 3578B72, 2835 Columbia St., Torrance, CA 90503 (213) 328-9560 contacting extraterrestrials, then this is a near certainty: technologically, they'd be as far in advance of 20th-century mankind as we are beyond Neandertalers.

To understand why, just consider the different ways in which contact might first occur. Barring telepathy, there are only four ways: aliens might visit Earth in a spaceship, they might stumble across a space probe of ours, our astronomers might detect their radio signals, or they might detect radio emission from Earth. All these scenarios, please note, require that the aliens' technology is at least as sophisticated as ours. But exact equality is extremely unlikely — if extraterrestrials were at least as advanced as we are, then it's more probable that they're ahead of us. And their lead, far from being a few decades, could easily be measured in millions of years.

Again, why? Look at the vastness of the galactic evolutionary time-scale. The Galaxy's myriad of stars and planets did not all come into being simultaneously: their births were spread over some 10 billion years. This must also be true of those planets' life forms. On some worlds life has only just begun; on others it could be nearly as ancient as the universe itself. And because the range of ages is so enormous, the probability of our encountering aliens at the same stage of development as ourselves is correspondingly small. We can no more hope to meet our galactic equals than you, today, can hope to meet a person whose age is within a second of your own.

No — we can be sure that whenever two galactic species make contact, one is always older than the other by 10 million years at least. And since we aren't going to be the senior race in such a contact — we've known of radio for less than a century! — we'd be meeting creatures that have evolved as far beyond *Homo sapiens* as *Homo sapiens* is beyond *Tyrannosaurus rex*. To us, they'd seem as mighty and terrible as gods, and to them, we'd be as helpless and backward as chimpanzees.

The corollary is obvious. If we ever do encounter aliens who are malevolent — then, to put it mildly, we'd have a problem. Aliens millions of years in advance of mankind would be all-powerful. No matter what they wanted to do to us — however dreadful — we'd be totally helpless. Suppose they had the policies of a Hitler — suppose that they wished to colonize every habitable world in the Galaxy. How might they feel about those creatures already living on Sol III? Would those vermin — us — be just a tiresome infestation to be liquidated? (What do you do with an

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anthill that's where you intend to build your house?) They might see the destruction of all terrestrial life as an act of simple hygene — and we could do absolutely nothing to prevent it.

Does this idea horrify you as much as it does me? Perhaps not. Maybe you think my argument contains a loophole. I've said that if we encountered aliens, they'd be our technological superiors by several million years. Is it conceivable that a race so advanced could behave like extraterrestrial Nazis? The answer, I'm afraid, is yes. Technological excellence does not imply moral excellence. Nothing in our history is plainer, or more tragic, than the gulf between cleverness and wisdom.

As century has succeeded century, we've learned more and more about the worlds around us and within us. Piece by piece, we've accumulated a hoard of scientific knowledge, but we've no more been able to turn that knowledge into lasting good than an alchemist could turn lead into gold. Better science, instead of making us into better people, has given us more ingenious ways of being wicked — more expensive, more elaborate, more efficient techniques of mass murder.

Nor, if you think about it, is the dichotomy between scientific cleverness and moral stupidity wholly paradoxical. Look into your own mind and heart. What you've learned — your own personal store of science — has no control over what you chose to do with this knowledge. Becoming a better engineer doesn't make you a kindlier person. I see not the slightest reason to believe that technologically sophisticated aliens would automatically be benevolent. They might have the same capacity for insane evil as we humans of the 20th century do. We're clever enough to have invented quantum theory and relativity — and depraved enough to have invented death camps and gas chambers.

I wish interstellar communication were just a pipe dream, but radio signals have already been beamed at several nearby stars. In June 1983, NASA's Pioneer 10 slipped into interstellar space bearing a message which, if aliens ever find it, will tell them Earth's precise location with all the clarity of a road map. And new communications schemes, more ambitious and more likely to succeed, are already being mooted.

In my view, all such projects are irresponsible. To seek to draw our world to the attention of extraterrestrials — beings of whom we know nothing except the fact of their irresistible power — I believe to be foolish to the point of lunacy. And it's also outrageously arrogant, for whatever the consequences of achieving contact, they would surely transform our entire world forever. Yet the handful of scientists who have sought communication have consulted no one's opinion but their own. No grosser contempt for democracy is imaginable.

Before we attempt interstellar communication again, its philosophical problems must be investigated in depth. And the investigation shouldn't be left to astronomers alone. Logicians, historians, psychologists, sociologists and, not least, writers of science fiction must all be asked to join in the discussion. The question to be debated is this: Can it be proven that if interstellar communication were achieved, the probability of consequent catastrophe would be zero?

If the answer is yes, then there's nothing more to be said and NASA will be able to proceed with their contact program. But if the answer turns out to be no — if it's recognized that to attempt communication is to invite a disaster as overwhelming as a thermonuclear holocaust — then all further contact projects should be banned. And never again ought NASA, or anyone else, try to knock on the door of an alien civilization — a door that might prove to be the very gate of Hell.

Richard Parlour
London, England

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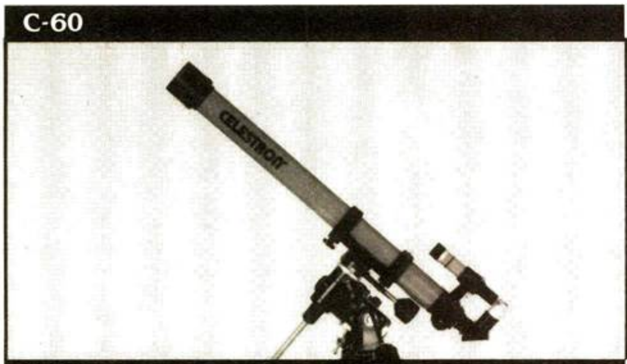

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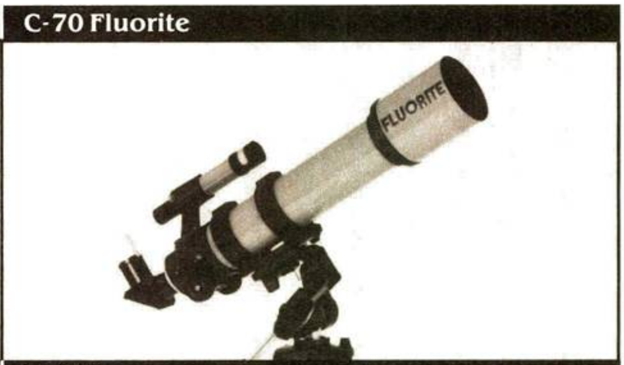

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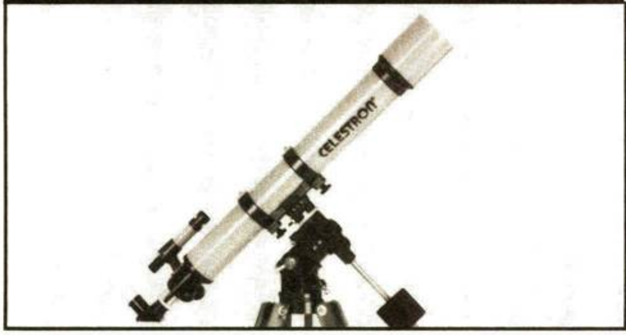

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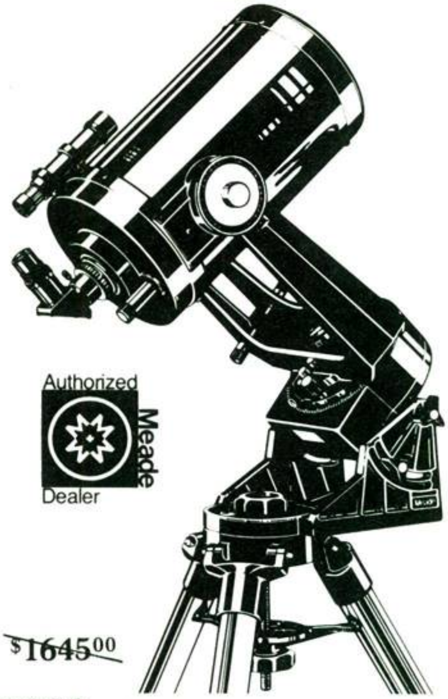

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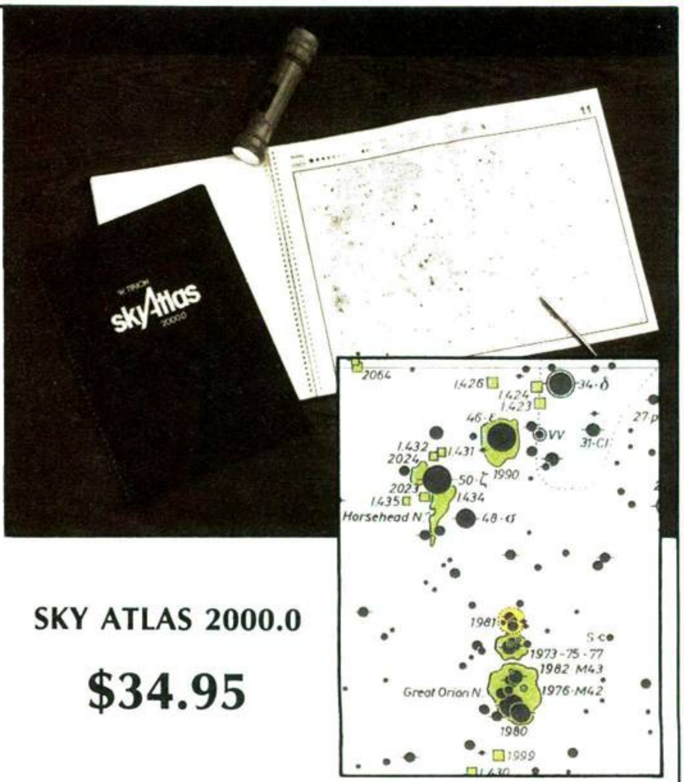

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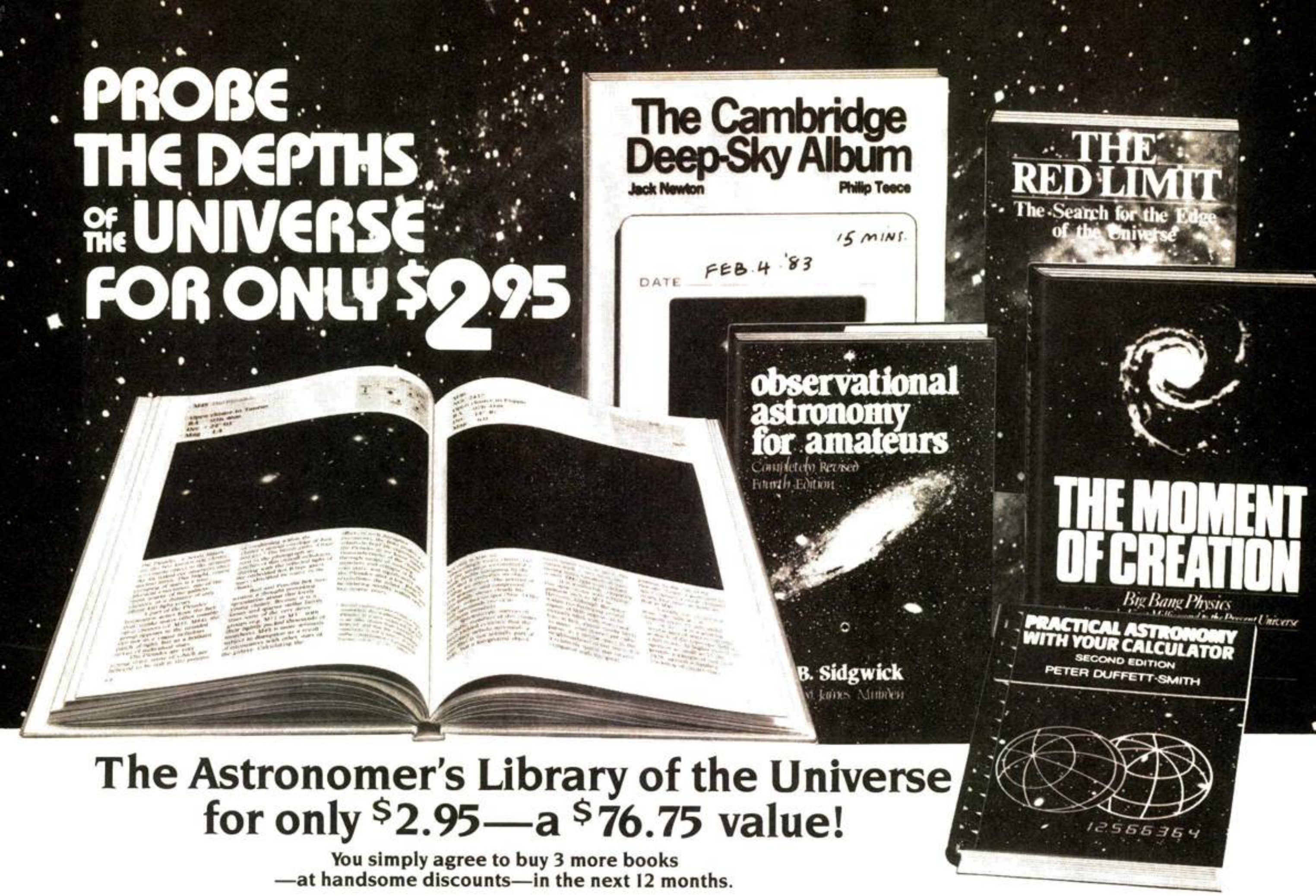
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Astronomy 7/84

ASTRONOMY
In Focus

Beam Me Up, Scottie!

Sir / Billy Pilgrim becomes "unstuck" in time. The answer to "life, the universe, and everything" is 46. A monolith teaches our ancestors a basic tool for survival. An alien race finds music the most efficient way to communicate with earthlings. Do any of these propositions stretch the imagination more than another?

Carol Rutter's "Hollywood Astronomy" asks us to believe the first three and dismiss the last. Without a doubt, she has picked three fine examples of how science *fact* can be incorporated in science *fiction* — but is it necessary to strictly obey the laws of the universe in our imaginations?

Kubrick's *2001: A Space Odyssey* is certainly the standard by which all science fiction films must be measured. I find myself watching it at least twice a year, just for the sheer joy of it. It's a shame that the NASA probes did not find a large, black monolith orbiting Jupiter — and based on Clarke's record, maybe they should look closer next time.

But the point is this: science fiction is not meant to catalogue future hardware. It is meant to explore the potentials and weaknesses of the human race and to enhance our imaginations.

In *The Day the Earth Stood Still*, Michael Rennie probably doesn't look any more like an alien than E.T.; Gort was a little scary, though! But this 1950s film makes all viewers wonder about *this* planet's sanity without the benefit of accurate aliens, spaceships, or other hardware. I hope the next edition of the *Encyclopaedia* still lists us as "mostly harmless."

Although *Star Wars, Close Encounters, E.T.*, and others may not be educational, they sure are fun. They spur the imagination and, I believe, have contributed to a renewed interest in space exploration. Without that imagination would this country be willing to spend the money necessary to build the Space Shuttle, the permanent space station, and send probes to the planets?

If we must stop enjoying movies like this — even when they aren't educational — I hope Scottie will beam me up right away.

Stephen Pehanich
San Jose, CA

Supercluster Credit

Sir / Though I'm no historian of science, I nevertheless feel it's important to give credit where credit is due. Thus I think Laurence Marschall's "Superclusters: Giants of the Cosmos" (April 1984) glosses over some fundamental historical details.

First of all, Edwin Hubble did not first notice that galactic spectra resembled those of stars: William Huggins had done this 50 years prior to Hubble's work. Neither did he measure the first redshifts — V.M. Slipher did this at Lowell Observatory just before World War I. Though Slipher had measured about 50 galaxies by 1925, it was Hubble (and ace observer Milton Humason) who recorded enough of them with the much larger instruments on Mount Wilson to show the relation between redshift and distance that we now know as the Hubble Law.

Finally, the galaxy supercluster "bandwagon" in the scientific literature might not have got rolling so soon without C.D. Shane and Carl Wirtanen's massive counts of galaxies at Lick Observatory. Their work figures into three of the five illustrations in the article, but they are not mentioned otherwise. Peebles and his colleagues assembled the counts into graphic form (p. 14), giving us an enigmatic glimpse of the filamentary large-scale structure of the universe.

Brian Skiff
Flagstaff, AZ

Hurrah for Computers!

Sir / The article in your April 1984 issue on computing times for sunrise and sunset, by William C. Bell, deserves a standing ovation! I am a computer hobbyist who reads many dedicated computer magazines, but not once have I ever seen such care and consideration given to a program. Many things make this program outstanding. For starters, the documentation should be a model for all programmers to follow. Most people have a tendency to be very skimpy in this area, if they document their programs at all, and some who document don't do it very well (probably by choice). Second, the indentation of the program body and especially the red and blue print for comments and code, respectively, made the program a pleasure to read (as opposed to "decipher"). Also, the modularity of the program could make even a Pascal programmer smile, since the program was split up into very definite sections that were set off by remarks to boot. Moreover, the program was well conceived. It was not a simple sunrise-sunset program, but one that gave all the other relevant data as well. But the real kick is that the program is compatible with any version of BASIC I have ever seen (five, to be exact). It was even written in a 40-column format for people who don't have 80-column screens! When I told another fellow microprogrammer, all he said was "WOW!" It is the only BASIC program I have ever copied that worked the first time I typed it in. I am so impressed that I would like a copy of the guidelines Mr. Bell used in writing his program in "Universal BASIC." I would very much like to be able to write programs that I know will run without modification on just about any machine.

However, we can't let Mr. Bell get away with perfection, can we? I would like everyone to note that the sample runs given in the article (not in the program itself) contain one consistent flaw, and that is that all the values for C DAWN are much too high. Indeed, how can C DAWN occur *after* SUNRIS? My program agreed with all of the other test values, so I believe these values for C DAWN are the correct values for the sample runs: 4.37, 7.48, and 6.25, respectively. Except for that very minor error, and the irrelevant fact that the zone should have changed in the test runs due to Daylight Saving Time (though the results are correct for the zone actually used), the article is perfect. Go ahead, take a bow, and then please try to come up with an encore. Thank you.

Joseph M. Brooks
New Hartford, NY

— As you surmise, we goofed in the printed example. When modifying the program so it would create a disk file of inputs and answers for typesetting, we inadvertently zapped the minus sign in line 384, making C DAWN wrong in our examples. Most readers recognized it as an error. The program is correct as printed. Several readers with Apple IIe's have noted that line 534 should be changed to IF A < M THEN GOTO 544 because Apple reads IF M > A THEN as IF M > AT HEN since AT is a reserved word in Applesoft. Readers with T/S 1000 computers noted that their BASIC requires THEN GOTO < line > instead of THEN < line>. Line 690 was blurry and hard for some readers to read. It is: 690 LET Z=Z−D. Clearly even Bell's "Universal BASIC" isn't universal, but it's pretty good. In the tradition of all great math books, we leave translating dialects as an exercise for the reader. Of course we should have changed the time zone for the winter months, but we didn't.

More on Aleph

Sir / According to the Brown Driver Briggs *Hebrew and English Lexicon of the Old Testament*, the word ('eleph), found in Psalms 8:8, means cattle. The first letter of the Hebrew alphabet is 'aleph, which is different only in the vowel pointings of the word (which were not supplied in the Old Testament until the time of the Masorites, about A.D. 1000). The shape of the letter has also been modified from the Old Hebrew character 𐤀 found in the texts of Mesha (about 840 B.C.) and the Old Aramaic character 𐤀 of Zenjirli (eighth century B.C.) *Gesenius' Hebrew Grammar*. This letter is also used in Hebrew as the number 1. These connections are sufficient to support Fred Schaaf's statements in the January 1984 Eye on the Sky.

Although Mr. Graber's letter in April 1984 is correct, his research lacks depth.

Robert J. Kish
Abilene Christian University
Abilene, TX

Automated Astronomy?

Sir / The letter from Russell Genet in the February In Focus somehow struck a sour note.

Technologically, I feel the work of Louis Boyd is quite commendable. A fully automated observing system! And without doubt, he is doing a job — photoelectric photometry — which is valuable to the science of astronomy. And as an amateur, he probably derives great enjoyment both from the actual assemblage of this system and because he is doing useful work.

I certainly hope, though, that he occasionally *looks* through his equipment. I don't do any "useful work" with my 8-inch f/6, my 13.1-inch f/4.5, or my 11 x 80 binoculars, but I wouldn't *think* of sleeping while my scopes were in use. Gathering data is one thing; observing the awesome majesty of the night skies is quite another. Makes me want to walk over at 2:00 a.m. and wake him up. (He lives just over a mile from me.)

Ah, well! I'm not doing anything for astronomy except enjoying every moment I can at the eyepiece (and, I suppose, keeping the accessory manufacturers/suppliers busy). But I enjoy every second of it. I go to bed — on weekends and whenever weather and work permit — only when the night sky gives way to dawn.

Jan M. Owen
Phoenix, AZ

Ooops!

The figure on page 11 of the April issue contains an arithmetical error — 7,500 cubic megaparsecs is equal to 260 million *quadrillion* cubic light-years.

Behind the Scenes

Toward Better Photos

At a time when professional astronomers are well on their way to abandoning photography in favor of arrays of cooled silicon diodes and third-generation cascaded microchannel intensifiers, a humble photographic film that anybody can buy at the local drugstore turns out to be really good for astrophotography.

I am referring to VR-1000 film. I shot my first roll of this stuff last year during the flyby of Comet IRAS-Araki-Alcock. The negatives were great, but drugstore prints left a lot to be desired.

Now, in this issue, Jack Newton demonstrates what the advanced photo technology of VR-1000 can *really* do. By cooling it to eliminate reciprocity failure, exposing on a large telescope, and using the right filter to remove light pollution, Jack has created images that are unique in the annals of amateur astrophotography.

Lots of readers have sent photos shot on VR-1000. Many are good, but when they aren't good, the problem is usually the same one I had — the film delivers, but machine-made color prints aren't up to snuff. Photofinishers just aren't set up for astronegatives.

There are two ways to get past this limitation. One is to become the photofinisher yourself, making color prints in a darkroom of your own. It used to be difficult, but Ektaflex now makes color print-making easier — faster, less fussy, less messy.

The second way is to shoot slides and stay away from darkrooms entirely. Once again, it's phototechnology to the rescue: super-fast 3M Color Slide 1000. But that's only the first of them. We're "star-testing" one new super-fast color slide film from Kodak and another from Fuji — but more about them in the months to come.

It will be fascinating to see how astrophotographers put these new films to use. Of course, we are interested in seeing your results. There is nothing difficult about sending photos to ASTRONOMY — just make sure your full name and address is written on each and every print or slide you send. Pack prints between stiff cardboard and slides in vinyl pages, then mail them to ASTRONOMY in a sturdy envelope.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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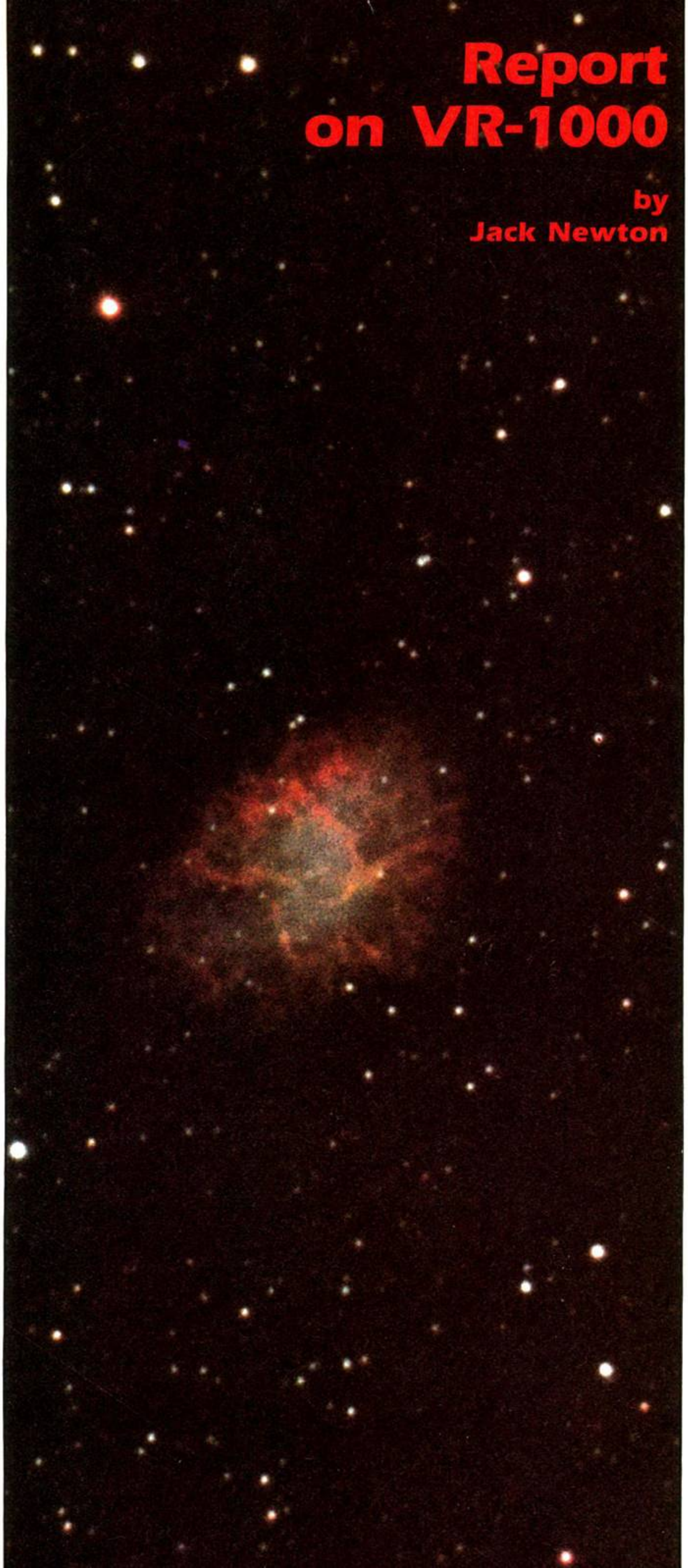
Photography in Astronomy

Report on VR-1000

by Jack Newton

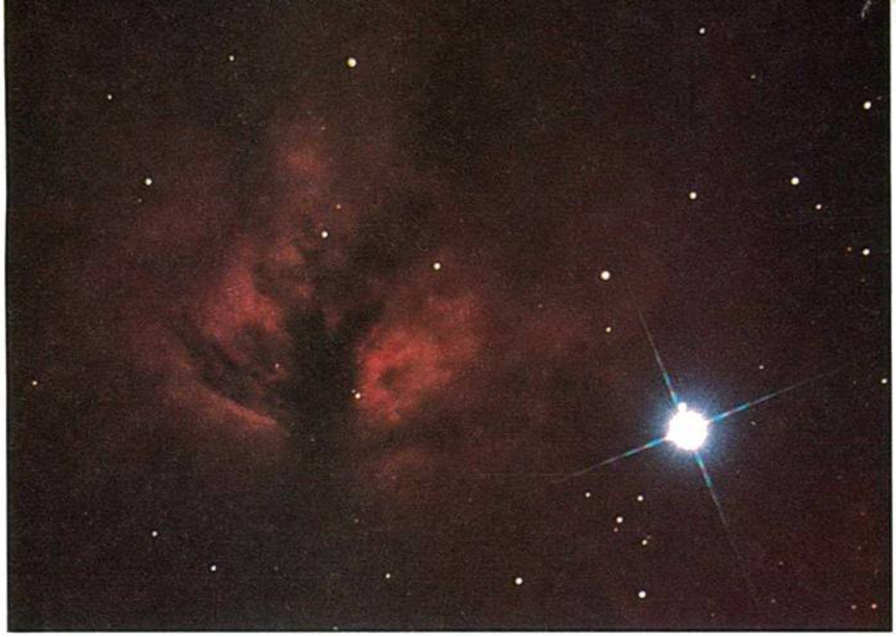


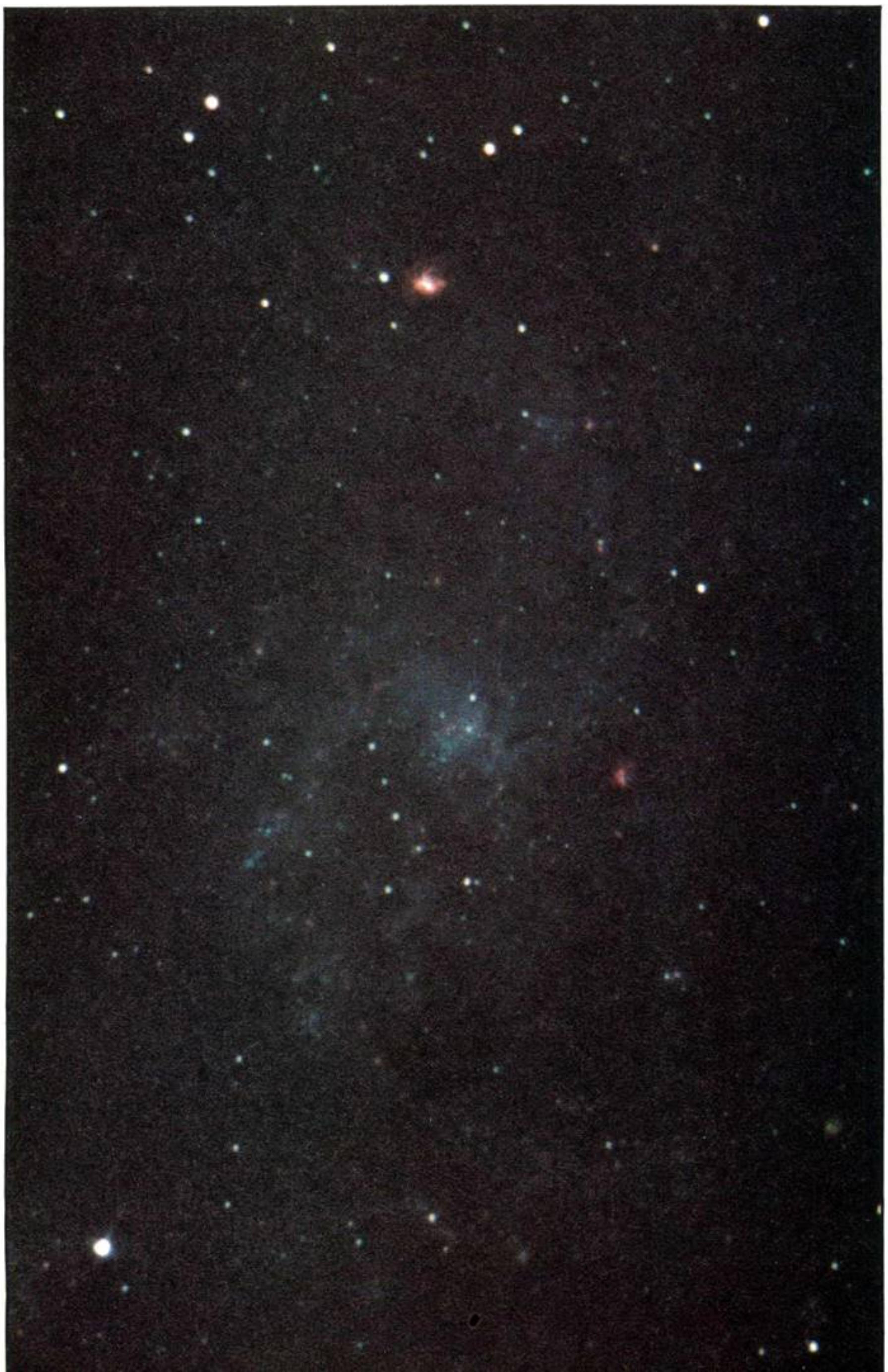
As someone with an active interest in making color photographs of deep-sky objects, I was excited when I heard about Kodak's new ultra-fast VR-1000 color negative film. I tried using some of it with my new 20-inch f/5 Newtonian telescope and the cold camera described in the February 1981 issue of ASTRONOMY. The film proved so fast, however, that the minimal light pollution at my observing site fogged the film. The pictures were overexposed and blue. I was discouraged. Still, not wanting to give up, I decided to try a nebular filter to cut skyglow and allow only light from the deep-sky objects to pass through to the film.

I had tried nebular filters for astrophotography when they first came out a number of years ago, but with disappointing results. Although they worked well visually, color pictures taken with them were terrible. The filters passed the deep red H-alpha line, the blue-green atomic oxygen line at 5007 Angstroms, and the blue H-beta line, and they successfully blocked the violet and yellow lines generated by mercury vapor lamps. But the resulting color pictures were unacceptably red, and internal reflections in the filter created spurious blobs of light on the pictures. A few years passed, and I tried the next generation of filters, but the results were again disappointing.

In the meantime, I was taking plenty of pictures on Ektachrome 400 color slide film, chilled in the cold camera to about −40° C. All films suffer to some degree

The Crab Nebula, M-1, is the brightest supernova remnant in the sky. This photograph was made with a 20-inch f/5 Newtonian reflector, VR-1000 film, a nebular filter, and a 20-minute exposure. (All other shots in this article were made with the same setup.) The result is a colorful, detailed view of the Crab's filaments, which expand into space at about 1000 km per second. All photographs in this article are by the author. Unless otherwise stated, north is up, east at left.





Left: The dim ruddy glow of NGC-2024, a large emission nebula, appears adjacent to the bright bluish star Zeta (ζ) Orionis, the easternmost "belt star" in Orion. The dark nebula bisecting NGC-2024 shows intricate structure in this 20-minute exposure. Below left: A nebular filter helped to produce this image of galaxy M-33 in Triangulum. The many small pinkish patches of light represent giant regions of ionized hydrogen in the galaxy. The largest one — at upper center — is NGC-604; it contains as much material as some dwarf galaxies.

from low-intensity reciprocity failure, the irritating tendency for the latent image to "leak away" almost as fast as it forms. With color films, the three color layers all behave differently, so color balance goes off in long exposures, too. Chilling the emulsion decreases these tendencies, making almost any film better for astrophotography. In particular, color films don't undergo strange color shifts.

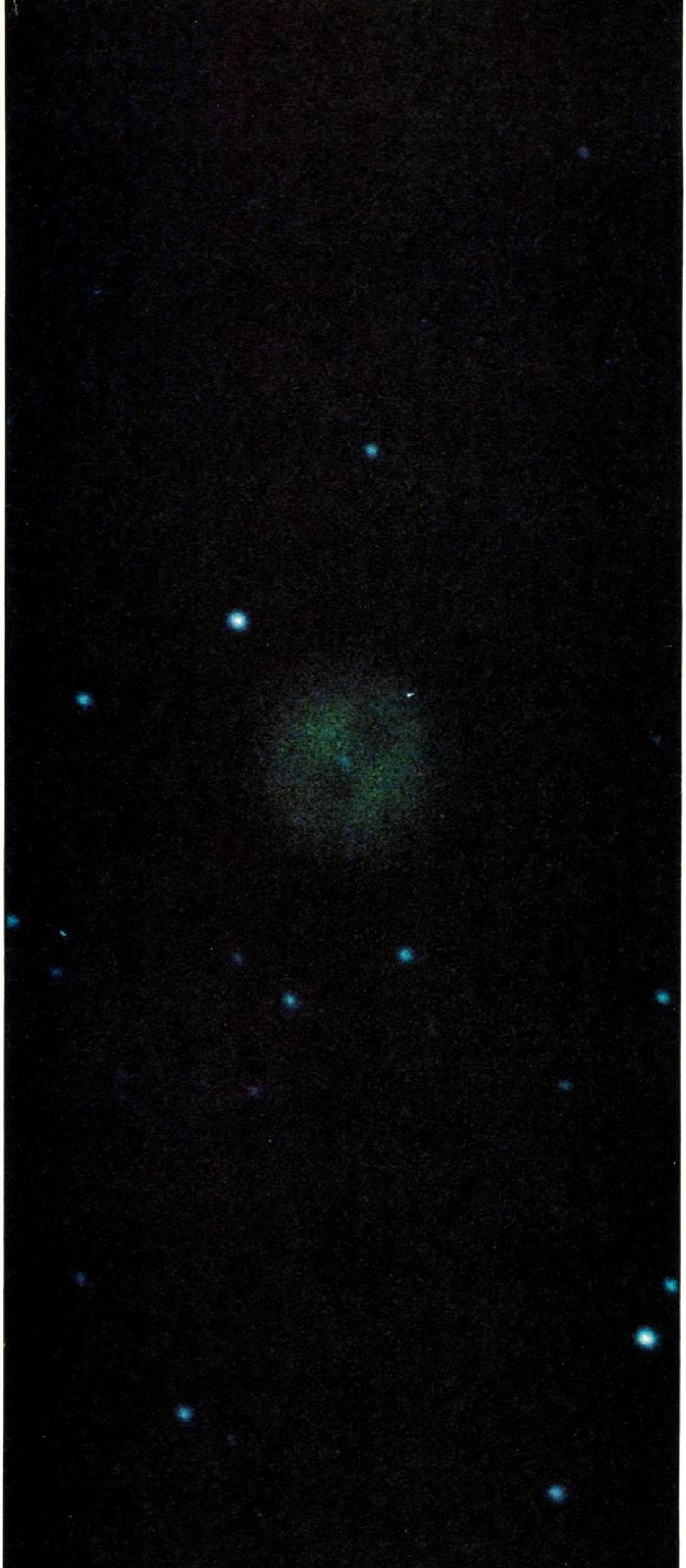
But chilling creates problems: frost forms on the film. My cold camera solves this problem with a tiny dry nitrogen chamber inserted in front of the film. Before starting an exposure, I purge the chamber with dry nitrogen gas for 30 seconds. During the exposure, dry ice chills the film from behind. Since there is no water vapor in the gas in the chamber, frost can't form on the cold film surface.

Hypersensitized films, especially the super fine-grain red-sensitive 2415 Technical Pan, are very popular today, and have replaced cold cameras to a large extent. The reasons are obvious: cold camera photography is tricky and demanding. With hypersensitizing, most of the special handling is done in a darkroom, in advance. My experience with Ektachrome 400 and Fujichrome 400 is that they're good when hypersensitized, but they're even better when chilled. Chilling locks in the color balance and pretty much eliminates reciprocity failure — so the image just keeps building up.

VR-1000's high blue sensitivity suggested that it might work well with the latest generation of filters. I purchased a Lumicon Deep Sky filter, placed it in the light path of my cold camera (as the front of the dry gas chamber) and set out to photograph my favorite sky objects once again with VR-1000. When the film came back — yes, I had it processed by the local drugstore — I was stunned! Never before had I seen such magnificent color or detail in such relatively simple pictures. The galaxy M-33 in Triangulum showed its little pinkish HII regions as I'd never seen them. The Owl Nebula, M-97, appeared distinctly *green* on the color slides. The Orion Nebula presented a tonal range of pinks, violets, blues, purples, reds, and whites that startled me.

VR-1000 is grainy — no doubt about it. But the film produces a very crisp image; using it, I feel I'm getting the most I've ever gotten with any color film. Certainly I've

The Owl Nebula (M-97) in Ursa Major, one of the finest planetary nebulae in the sky, glows green in Jack Newton's 30-minute exposure on VR-1000. Visible are the twin "eyes," first recognized by Lord Rosse — who gave the nebula its nickname — and the subtle glow of the Owl's 14th magnitude central star.



never seen so much density in astrophotographs; with this stuff they come thumping through.

On the down side, VR-1000 is not very good for long-exposure astrophotography without cooling. In a typical 12-minute exposure without a nebular filter at temperatures around 10° C, the sky background comes out a muddy brownish-green. Chilling to −40° C increases its effective speed by a factor of four, giving a dark blue or blue-green sky background. It reaches stars down to 18th or 19th magnitude with my 20-inch telescope in a 12-minute exposure without the filter. VR-1000's high speed is vital because the Deep Sky filter blocks a lot of light. For good results, my exposures with the filter must be triple what they are without it.

Why does VR-1000 work so well with the Deep Sky filter? Kodak developed VR-1000 for photography in low-light situations where conventional color films fail. Since most low-light situations are lit by tungsten light bulbs, they engineered the film for high blue and violet sensitivity. Coupled with a nebular filter that transmits more blue light than previous filters, VR-1000 records light over the whole visible spectrum. Its high violet and blue sensitivity picks up the blue stars in the arms of spiral galaxies. The middle wavelength passband of the filter transmits the important green and blue-green oxygen and H-beta lines of planetary nebulae; H-alpha comes through loud and clear in the red, recording HII regions and other red nebulae nicely.

One pleasing advantage is that I can make color prints from the VR-1000 negatives — this means I have further control over the color balance and density of the print. I can also make color slides by copying the negatives using Kodak 5072 high-contrast negative copy film. I use an inexpensive Soligor slide duplicator with Cibachrome color correction filters to obtain the color balance I want.

In conclusion, VR-1000 is good stuff for long-exposure chilled-emulsion astrophotography, especially when combined with the right filter. Of course, more testing should be done. I haven't tried it hypered yet; for now I'm happy with chilled VR-1000. But let me tell you about a test roll of Fuji-400 I just shot just the other night. . . .

Jack Newton is an executive at Marks and Spencer, a large retail store, in Victoria, B.C. He is an avid astrophotographer and has contributed many celestial photographs to ASTRONOMY.

ASTRONOMY Reviews

TellStar, level II
5¼" floppy and manual, $79.95
Scharf Software Systems (1984)

TellStar is a program, formatted for IBM PCs and Jrs and Apple IIs (and II+ and IIe), that shows you what is in the sky at any time on any date between 0 AD and 3000 AD. (However, Scharf claims excellent accuracy between 1980 and 2000 only.) The manual that accompanies the floppy is complete and in general clearly written. When you boot the disk, it assumes you live in Boulder, Colorado (where Scharf Software is), but it is easy to input any other location and save the data so that when you next turn the program on, it knows where you are.

TellStar prompts you by asking for date and time, and then returns the UT and sidereal time for the local time you input, plus the day of the year. At this point, you can ask for a display of the sky's objects. If you choose this — the alternatives are going into "utilities" subroutines, inputing a new time or place, ending the program, or printing out the contents of the screen — TellStar then asks which database you'd like: northern or southern hemisphere, or the Messier list.

The northern and southern hemisphere files have about 240 objects each, including the main stars in the appropriate celestial hemisphere and those in the opposite hemisphere visible from middle latitudes, plus a few of the brighter Messier objects. The Messier list database has, again, about 240 objects — 110 in the list proper, plus the brightest stars. All three databases include the nine planets and the Moon, and the first two also include the Sun.

When you've chosen your database, the computer goes off to do its calculations. This takes about three or four minutes. Meanwhile, the screen display tells you what it is doing so you won't think the program has quietly died.

Once the calculations are finished, you get a horizontal display — you are looking south (in the northern hemisphere) or north (in the southern), and the screen shows the sky from horizon to overhead in its vertical dimension and from southeast to southwest in the horizontal. (Of course, this projection inevitably distorts the shapes of the high-elevation constellations.) The Sun (if it's visible) is a large white disk, the Moon is shown in its proper location (though a Last Quarter Moon is displayed for First Quarter and vice versa), the stars, planets and other objects are all in their correct places.

The accuracy seems good — I asked it to display the sky for the mid-afternoon when I was testing the program and, sure enough, the Sun *was* over in the southwest and the Moon *was* about 10° high in the east. Advancing the time about six hours (which required another four-minute recalculation, of course) correctly displayed the stars and objects that I saw later that night.

You can scroll the display in azimuth, with the machine moving you half a screen in either direction at a time. But because the program uses up so much of the machine's memory, you find that you can scroll only twice in azimuth without a pause. When you call for scrolling the third time, the new display is plotted about halfway and then stops. You must wait for about 10 seconds while the program clears out unused memory, reassigns it, and finishes plotting the screen. This characteristic is slightly annoying at first and more annoying on longer acquaintance, but perhaps you'd eventually get used to it.

Besides the scrolling commands, you can also place a cross-hair cursor in the display and move it on top of any object. The machine can then tell you what the object is — M-94, say — though the information is not exactly what I'd have wanted. You get the object's name and magnitude, time of rise and set, r.a. and dec., altitude and azimuth. Fine — but if you don't know what M-94 *is*, you have to look the object up in the appendices of the manual! (Moreover, M-94's magnitude is not variable, as the machine claims for it and a great many other non-variable objects.)

Minimizing the confusion from the distorted projection are helpful lines connecting the bright stars of each constellation — though Leo comes out looking quite distorted anyway, since the program places Regulus practically in Cancer! Another problem is that stars have only two magnitudes: "bright" and "less bright."

You can ask for an overhead display instead of a horizontal one. The zenith then falls in the center of the screen, and you see objects down to 45° off the horizon. You can record a copy of any one screen and call it up again whenever you like, and the contents of any screen can be printed.

This program provides good and useful information, but don't expect the display to show you a facsimile of the night sky. Bearing in mind the flaws noted above, I recommend it for anyone with the appropriate computer who wants a basic do-it-yourself almanac. *Robert Burnham.*

Sci-Mate^{TM} Universal On-Line Searcher
floppy diskette and manual, $440.00
Institute for Scientific Information
3501 Market St.
Philadelphia, PA 19104

This is a personal computer user search program, aimed primarily at scientists, which can search over 300 databases in medical, scientific, and social science host systems: SDS, DIALOG, BRS, NLM, and ISI, plus such online host systems as Dow Jones, The Source, CompuServe, and MINet. It features automatic dial-up and log-on, integrates on-line search with off-line processing to allow the results of an on-line search to be incorporated into a personal data manager. Versions for IBM PC, IBM XT, Wang PC, Apple II, IIe, or II+, and Vector Graphic 3 and 4 are on 5¼" diskettes; TRS-80 models II and 12 and other CP/M-80 systems use 8-inch floppy disks.

Amateurs: On the Margin Between Work and Leisure

Robert A. Stebbins
280 pages, hardcover, no price given
Sage Publications (1979)

This isn't an astronomy book as such, but it has interesting things to say about our hobby and the way we go about enjoying it. ASTRONOMY's readers may recall Jo-Ann Pluciennik's "Stargazers of the World — Unite!" (August 1982), in which she strongly defended the rights of casual stargazers — those who enjoy the beauty of the heavens without feeling compelled to contribute to science as "serious" amateur and professional astronomers often do. A fair enough proposition, but just what *is* an amateur astronomer?

In his book on amateurs in the theater, archaeology, and baseball, Stebbins differentiates between professionals, amateurs, hobbyists, and dabblers. As he sees it, initially some new area of study is not sufficiently well-known or accepted to support full-time professionals, so the pioneering work is often done by hobbyists or unpaid "gentlemen." As the field develops, however, professionals appear; since they devote full time to their endeavors, they soon set new and higher standards of excellence for practitioners. After this threshold is passed, new people entering the field fall into one of three categories. If they reject the standards, they are dabblers. If they accept the standards, they are either amateurs (avocation) or professionals (vocation). (What about hobbyists? In fields where there are no professionals, such as canoeing, stamp collecting, and so on, the serious enthusiast is a hobbyist.)

Stebbins suggests that amateurs are "marginal" in four respects. First, because they take their leisure very seriously, they tend to be misunderstood by friends and neighbors. While their accomplishments are often respected, the amateur is often viewed as being at least a bit quaint. Second, amateurs tend to approach their avocation in such a serious, dedicated way that it inevitably conflicts with family time, family budgets, and other commitments.

Third, while they have respect for the professionals in the field and strive to meet the standards of the best, amateurs are usually considered outsiders by the professionals. Finally, the necessity of meeting only the highest professional standards with limited training, time, and resources necessarily leads some amateurs to frustration.

Stebbins has examined amateur astronomers specifically in his research papers. According to Stebbins, amateur astronomers are those that engage in the same activities to the same standards as professional astronomers — that is, scientific research using modern techniques and methods. (By this definition, there may be even fewer amateur astronomers than professional astronomers!) Paraprofessional or volunteer astronomers are those that assist professional astronomers by doing supportive tasks that the professionals do not themselves do. The astronomer hobbyist, while not engaging in scientific research or directly supporting those that do, is nevertheless serious about and committed to the hobby on a long-term basis.

While it does a good job as far as it goes, Stebbins's classification scheme still fails to accommodate amateurs such as Rev. Robert O. Evans, the Australian amateur who has visually discovered five supernovae in galaxies. Without question, these were important discoveries, yet I know of no professional astronomers making visual searches for supernovae. Similarly, the AAVSO's many visual variable star observers unquestionably make important scientific contributions, yet once again these would not be included because professional astronomers switched from visual to photoelectric observations of variable stars many decades ago.

It appears that amateurs who choose to can contribute to science in unique ways not available to professionals. But I wonder just what sort of reception the proposal would get if a professional astronomer wanted to memorize the stars in and around 600 different galaxies so he could search visually without star charts? Yet this is exactly what Evans did! *Russell M. Genet.*

God and the New Physics

Paul Davies
255 pages, hardcover, $15.95
J.M. Dent (1983)

While the title of this work implies that it will be somewhat like Robert Jastrow's *God and the Astronomers*, it isn't. Instead, Paul Davies has written a bold, fascinating, and probing book on the cosmological and theological doctrines that shape our minds and lives today.

Right from the beginning, Davies makes it clear that the God to which he refers is not the traditional God of organized Judeo-Christian religion, but simply the creator of the universe and its natural laws. After pointing out succinctly the very different natures of science and religion, and their respective strengths and weaknesses, he asks whether current scientific evidence supports the notion of such a deity or abolishes it altogether.

That the universe appears *not* to be infinitely old, but that it had a definite beginning roughly 18 billion years ago, is supported by galactic redshifts, microwave background radiation, and even the Second Law of Thermodynamics. How then, the author asks, could the universe have come to be? In response, he cites some of the most daring and convincing conjectures from modern physics and cosmology.

The startling nature of quantum theory and its probabilistic, rather than absolute, interpretation bears strongly on a number of other profound questions regarding origins. Likewise, the attempts of physicists today to interweave all four fundamental forces of nature into a single, unifying "superforce" are well presented. If such a unification is possible, then it appears that physical laws themselves were "frozen out" during the first moments of the Big Bang, and today are merely low-temperature expressions of what happened back then.

Towards the end of Chapter 13, Davies makes one of his strongest statements against a supernatural creation of the universe:

"Our conclusions must be that there is no positive scientific evidence for a designer and creator of cosmic order. Indeed, there is strong expectation that current physical theories will provide a perfectly satisfactory explanation of these features."

But only a little farther ahead, he adds:

"The seemingly miraculous concurrence of numerical values that nature has assigned to her fundamental constants must remain the most compelling evidence for an element of cosmic design."

Davies nonetheless draws a clear distinction of the limits to practicing physical theory:

"Physics can perhaps explain the content, origin, and organization of the physical universe, but not the laws (or superlaw) of physics itself. Traditionally, God is credited with having invented the laws of nature and created the things on which those laws operate."

Davies then provides one solution to the dilemma, which the reader can accept or reject:

"Perhaps the laws — or the ultimate superlaw — will merge to be the only logically possible physical principle. . . . Could it be that the universe is the way it is because it is an inevitable consequence of logical necessity?"

Along with its main argument, the book also features two dialogs — one between physicist and skeptic on the nature of time, the other between a believer and a skeptic on the interpretation of miracles. In them, the author strives to be impartial, yet it is not hard to see where his sympathies lie. The answers that emerge from the discussion leave the reader free to make his own choices. As such, it is a very satisfying piece of work.

I found this book at once stimulating and challenging; it will prompt much lively discussion among friends and colleagues. I highly recommend it as one of the foremost books on scientific thinking to emerge recently. *Jordan D. Marche.*

Standard Handbook for Telescope Making (Revised Edition)

Neale E. Howard
356 pages, hardcover, $15.95
Harper & Row (1984)

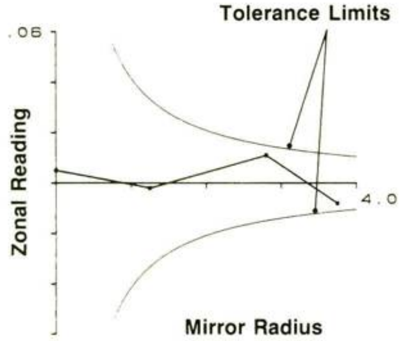
In amateur telescope making, we have a small set of books we call the "classics." They include the three *Amateur Telescope Making* volumes edited by Albert Ingalls, *How to Make a Telescope* by Jean Texereau, *Making Your Own Telescope* by Allyn Thompson, and the first edition of this book by Howard. All of these books were written before 1960. Since then we've had a "dry" period of nearly 25 years when practically nothing was published on the subject of amateur telescope making outside of the magazines.

In recent years, *Telescope Making* magazine has had a small but steadily growing readership, and this success has apparently convinced publishers that telescope-making books were not guaranteed to fail. During 1984 three telescope-making books will come rolling off the presses. Besides Howard's book, we should see a translation of Jean Texereau's much expanded second edition, and Richard Berry's *Build Your Own Telescope*.

Howard's *Standard Handbook* is a straightforward guide to producing an 8-inch f/7 Newtonian reflector. In an early chapter, Howard argues persuasively for the Newtonian as a reasonable project for the beginner and selects the 8-inch as the largest mirror the novice has a significant chance of successfully figuring. I made an 8-inch mirror as my first project, so I can personally attest to the soundness of his logic. Similarly, his choice of a focal ratio of f/7 is based on ease of figuring, but he says that is not the only reason: ". . . focal ratios lower than 6 or greater than 9 begin to develop certain unfortunate characteristics, both in the use of the instrument and in the details of manufacture." I wholeheartedly agree. Newtonians at f/7 or f/8 are at the nadir of popularity right now, but I really don't know why. Their relative insensitivity to misalignment makes f/7 or f/8 Newtonians great for beginners, who generally don't know how to critically align a fast instrument. I predict an upswing in the popularity of f/8 Newtonians as people rediscover how well they work.

I have to admire the *Standard Handbook's* section on mirror making. I don't have a window into Howard's mind, but I think he consciously tries to tell you the process three times. First, he has an overview chapter at the beginning, where he roughly sketches out what you will be doing from first to last. Second, he has a series of "detail" chapters telling you every aspect of mirror making. And third, he has a little summary section at the end of each chapter to repeat what has gone before. This approach really drives the lesson home.

There is one glaring fault, however, with regard to mirror figuring. On page 127 in his chapter on parabolizing, Howard shows a graph of theoretical Foucault tester results with the measurements plotted on top of them. The problem with this graph is that the tolerance curve is shown opening up toward the outside of the mirror. In 1976, Adrien Millies-Lacroix demonstrated that the true tolerance envelope of a diffraction-limited mirror opens up *toward the center*. I have replotted the example measurements appearing in Howard's book according to the prescription set forth by Millies-Lacroix (minus the parabola) in the accompanying figure.



We see that the measurements fall within the tolerance curve, but if we want a truly superb mirror, we must reduce the 70% zone. This defective graph is not totally Howard's fault. It originally appeared in an article by Franklin Wright in *Amateur Telescope Making* (book 1), and has been bouncing around ever since. Wright's method ties the whole graph to the difficult-to-measure central zone — a very bad move from a number of viewpoints. Wright originally published this graph with a caveat about making the edge zones behave, but people have tended to forget the warning.

Either Millies-Lacroix's or Wright's method will result in a reasonable first mirror, but it's unfortunate that the more correct method wasn't used here. When you write for hardbound books, you may as well be chiseling in stone. Howard has ensured that Wright's dubious graph will survive another 25 years.

Another small complaint I have is about the star test on page 230, which is drawn from the image pattern of a hyperbolic mirror. I think that Howard is trying to scare his poor readers!

Howard also leaves intact an antiquated section about making diagonals, but freely admits in the beginning of the chapter that most people buy their diagonals. (An annoying tendency among some telescope-making authors is to demand that the reader manufacture every last little part of the telescope — Howard is delightfully free of such prejudices.) He mentions buying eyepieces and gives a modernized review of the various designs, but offers a section on making simple eyepieces for people who like to tinker. He seems to have written complete instructions on building an observatory, but I have never built an observatory and can't critique him.

Overall, I wish that this book had been more heavily revised. I find it difficult to believe that after 25 years Howard was satisfied with merely a polished-up reprinting. An example of this attitude is the disappointingly brief section on Dobsonian mountings and the Poncet platform. These important recent developments surely deserve a more thorough treatment than the few pages devoted to them here. Particularly poor was the description of how a Dobsonian turns in azimuth. I asked myself, if I didn't already know how to build a Dobsonian mounting, would this book teach me? The answer was no.

In sum, I have to recommend this book, if only for the mirror-making chapters. The *Standard Handbook* will instruct the beginner as well as it did when the book was first published 25 years ago. But if you possess the first edition, save your money. You already own this book, except for a number of unimportant details. *Dick Suiter.*

Experiments in Space Science

Peter Greenleaf
166 pages, paperback, $4.95
Arco (1983)

A revised and updated edition of a work that first appeared in 1969 as *Let's Explore Outer Space*, this book provides a number of simple but interesting experiments you can perform with minimal apparatus. Included are: measuring the Moon's orbital speed with a camera, capturing micro-meteorites with a pie plate and Saran Wrap, drawing the Earth's orbit around the Sun to scale, and others.

Sci-Mate™ Personal Data Manager

floppy diskette and manual, $540.00
Institute for Scientific Information (1983)
3501 Market St.
Philadelphia, PA 19104

This is a random access data storage program with a menu-driven command system. It allows the user to create a mini-database of research notes, abstracts, citations up to 1,900 characters per entry, and up to 32,000 records per file; no key-wording or pre-indexing is necessary; and it allows searching by character, word, and phrase. "Given only the vaguest recollection of what is sought, [the program] can rapidly provide the data or citation." Versions for IBM PC, IBM XT, Wang PC, Apple II, IIe, or II+, and Vector Graphic 3 and 4 come on 5¼" diskettes; TRS-80 models II and 12 and other CP/M-80 systems use 8-inch floppies.

Astronomy Handbook
James Muirden
189 pages, hardcover, $8.95
Arco (1983)

This pocket-sized, full-color illustrated manual is designed to help beginning amateur astronomers get squared away on such topics as the celestial sphere, how a telescope works, the types of celestial objects to be seen, the brightest stars in each constellation, and so on. No topic is dealt with in depth, but the coverage is broad. It also includes a Moon map and a simple star atlas.

Powers of Ten
Philip Morrison and Phylis Morrison
150 pages, hardcover, $29.95
Scientific American Books (1982)

Powers of Ten is the print version of the standard "scale of the universe" movie — by the late Charles and Ray Eames — shown in nearly every high school science class in the world. Subtitled "About the Relative Size of Things in the Universe," the book begins with a scene of a man and a woman picnicking near Lake Michigan and Chicago's Lake Shore Drive. With this setting in mind, the authors create 42 frames, beginning with a view of superclusters of galaxies and zooming in each frame by a factor of ten. Halfway through the journey, after reaching the man's hand, the book probes the depths of the microcosm, closing in to inspect cells and finally individual atomic nuclei and electrons.

Rockets, Missiles, and Spacecraft of the National Air and Space Museum
Gregory P. Kennedy
165 pages, softcover, $6.50
Smithsonian Institution (1983)

This volume contains black and white photographs of the National Air and Space Museum's most important exhibits, including: a captured German V-2 rocket; Chuck Yeager's Bell X-1, in which he first broke the sound barrier; the Mercury *Freedom 7* capsule, in which Alan B. Shepard became the first American astronaut; the Apollo 11 command module; the Apollo lunar rover, "humanity's most expensive vehicle"; a mockup of Pioneer 10; and a 1/15 scale model of the Space Shuttle *Columbia*.

The New Cosmos, 3rd edition
Albrecht Unsoeld and Bodo Baschek
479 pages, softcover, $29.80
Springer-Verlag (1983)

This popular/semi-technical review of progress in observational and theoretical astronomy is now updated through 1982 and contains useful information about classical astronomy, the Sun, variable stars, galaxies, double stars and their masses, classification of stellar spectra, radio emission from galaxies, cosmology, interstellar matter, and the evolution of life on Earth.

Dynamical Trapping and Evolution in the Solar System
Vassilis V. Markellos and
Yoshihide Kozai, eds.
424 pages, hardcover, $58
Reidel (1983)

This book contains the proceedings of an IAU colloquium held in Gerakini, Chalkidini, Greece, during August 1982. Its seven sessions covered the dynamics of satellites and planets, comets and meteor streams, asteroids (two sessions), periodic orbits, trapped motion in the three-body problem, and miscellaneous dynamics. Unfortunately, the IAU colloquium on planetary rings coincided with this meeting, so the proceedings contains no papers on the dynamics of ring systems.

Solar Terrestrial Physics: Principles and Theoretical Foundations
R.L. Carovillano and J.M. Forbes, eds.
859 pages, hardcover, $115
Reidel (1983)

This tome examines the theoretical foundations of the complex processes in the solar-terrestrial system. The book provides comprehensive treatments of magnetohydrodynamics, kinetic theory, plasma waves and instabilities, plasma turbulence, planetary fluid dynamics, electrodynamics, and photochemistry. *Solar Terrestrial Physics* is designed to be used as a primary text for a graduate course, but students using the book will need a background in electromagnetic theory and elementary plasma physics.

B.A.A. Star Charts
Wil Tirion
Set of 5 sheets in envelope, $9.95
Enslow Publishers (1983)

These magnitude 6.5 star charts were originally commissioned by the British Astronomical Association for the benefit of its members; they have now been reprinted in the United States. Drawn by celestial cartographer Wil Tirion, the set consists of five 13½" x 18" sheets, three covering the equatorial sky and two the polar areas. The coordinate epoch is 1950. Cartographic conventions similar to those in the Skalnate Pleso *Atlas Coeli* and *Sky Atlas 2000.0* (also by Tirion), are used in plotting stars and deep sky objects. The B.A.A. sold the original set for the equivalent of $3, delivered rolled in a tube; the current edition costs three times that and each map is folded down the middle.

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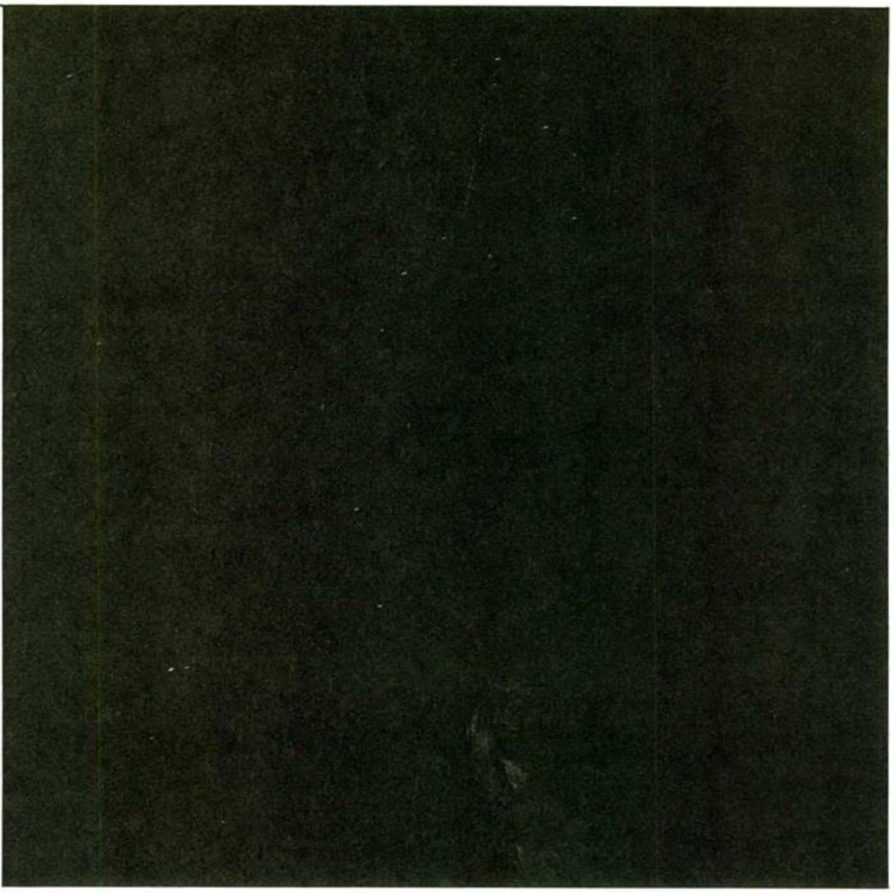
Eye on the Sky

Outer Planets Dominate

by
Fred Schaaf



The constellation Scorpius the Scorpion lies on the meridian as July twilight fades. Karl Kernberger snapped the figure's twisting form from the New Mexico desert.

Gleaming above the snow-capped Grand Tetons in Wyoming, the brilliant planet Venus forms a right triangle with the stars Castor and Pollux in Gemini. Dewey Vanderhoff used 400-speed film, an 85mm lens set at f/2, and an 18-second exposure for this shot.

The Wanderers

July offers a great opportunity to study the outer planets, all bright and well-placed in the southern sky. In addition, the Moon will not interfere with the peak activity of the Delta Aquarid and Capricornid meteor showers at month's end.

Although the year's planetary oppositions are over, the second half of 1984 begins with the brightest outer planet just two days past opposition. Brilliant **Jupiter** (magnitude −2.7) lies due north of the Teapot of Sagittarius. Jupiter, the solar system's principal planetary mass, passes south through the plane of the Earth's orbit (the *ecliptic*) for the first time in 12 years. Jupiter lies right on the ecliptic on July 24. The big planet slows in its retrograde (westward) movement, but will not halt until the end of next month.

Mars and **Saturn** are both far ahead of Jupiter in their nightly journey, rising at least an hour before it. The Red Planet skirts just a few degrees south of Alpha (α) Librae around midmonth, ending July near faint Iota (ι) Librae. Mars continues to lose brightness rapidly but does not yet dwindle to the radiance of Vega or Arcturus. Saturn, on the other hand, barely outshines Spica by month's end. This golden planet seems fixed in extreme western Libra, its retrograde motion halted on July 14. Mars and Saturn now lie between Alpha Scorpii (Antares, whose name means "rival of Mars") and Spica (Alpha Virginis). By early August, Mars is about as far from Antares as Saturn is from Spica.

From North America, a waxing gibbous Moon is close to Saturn and Mars on the evening of July 7, enters the head of Scorpius on July 8, and lies near Antares and Uranus on the 9th. On July 11, the nearly Full Moon makes a fine sight just south of Jupiter.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Mercury is at its greatest eastern elongation on July 31 — 27.3° from the Sun, its largest separation of the year. Nevertheless, Mercury's altitude in midnorthern latitudes is not very good at this apparition: look for the planet very low in the west-northwest in twilight a little before midmonth and just a little north of west by month's end.

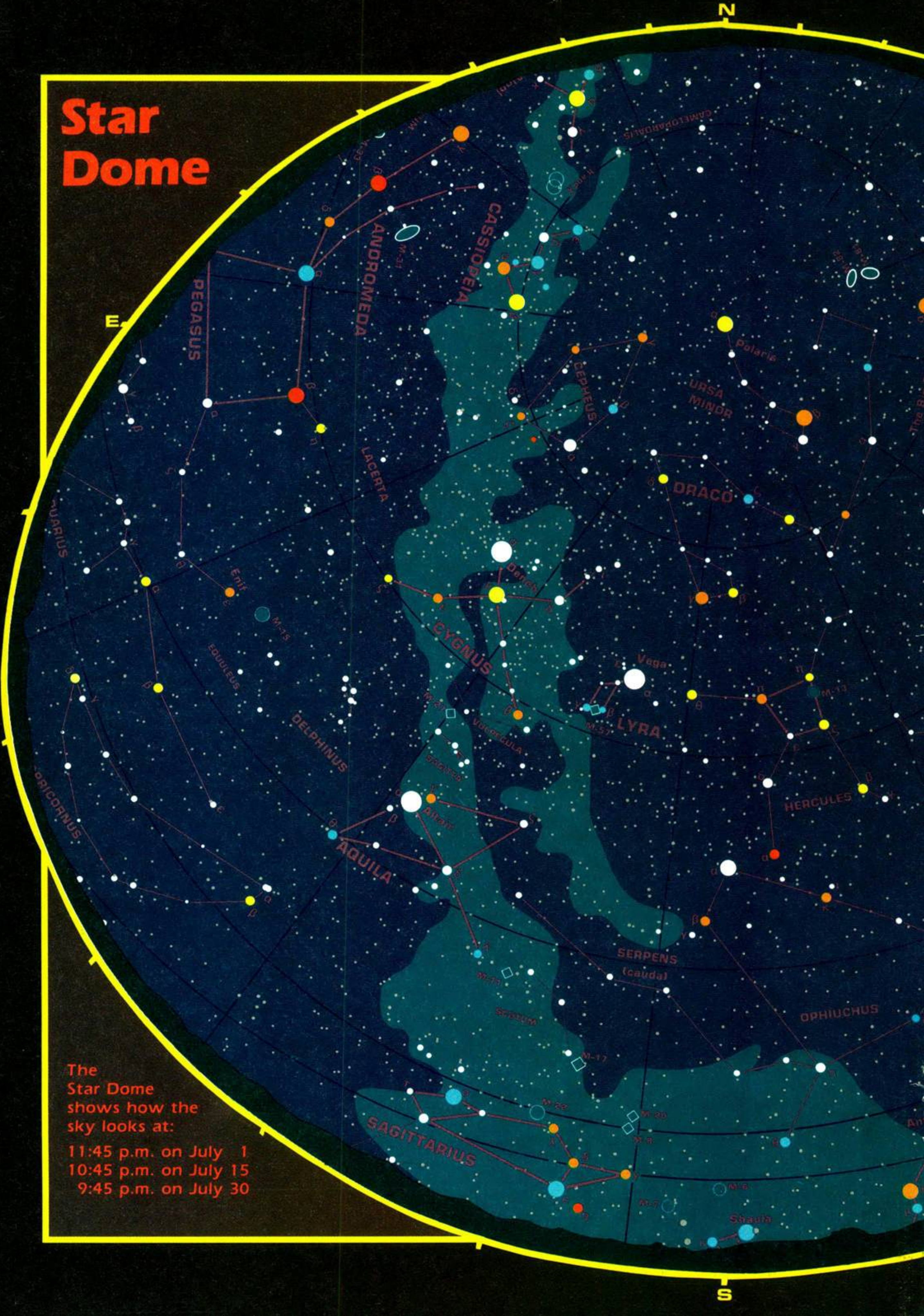
During this time, Mercury fades from about magnitude −0.3 to +0.6, and has some interesting conjunctions — unfortunately with objects that are, with one exception, too dim to see low in the twilight. The only star that might be seen near Mercury this month is Regulus (Alpha Leonis), less than a degree — more precisely, 49 arc-minutes — north of the tiny planet on July 25 (for North America).

Magnitude −3.9 **Venus** is difficult to spot this month despite its brightness — it's only about 7° above the horizon at sunset even by the end of July. Its ascension into prominence over the next few months will be slow. Try spotting Venus with naked eye or binoculars in the west-northwest on the 28th, when it is just a few degrees left of a thin crescent Moon.

In June, Venus was at superior conjunction and actually passed behind the disk of the Sun for just the second time since 1902. How often do the other planets pass behind the Sun? Mercury does it about two or three times a decade. Jupiter and the outer planets linger near the ascending and descending nodes of their orbits, and therefore generally are occulted by the Sun at least once every half orbit. Uranus is occulted by the Sun's disk every year between 1980 and 1989 (Uranus will pass through its descending node this December).

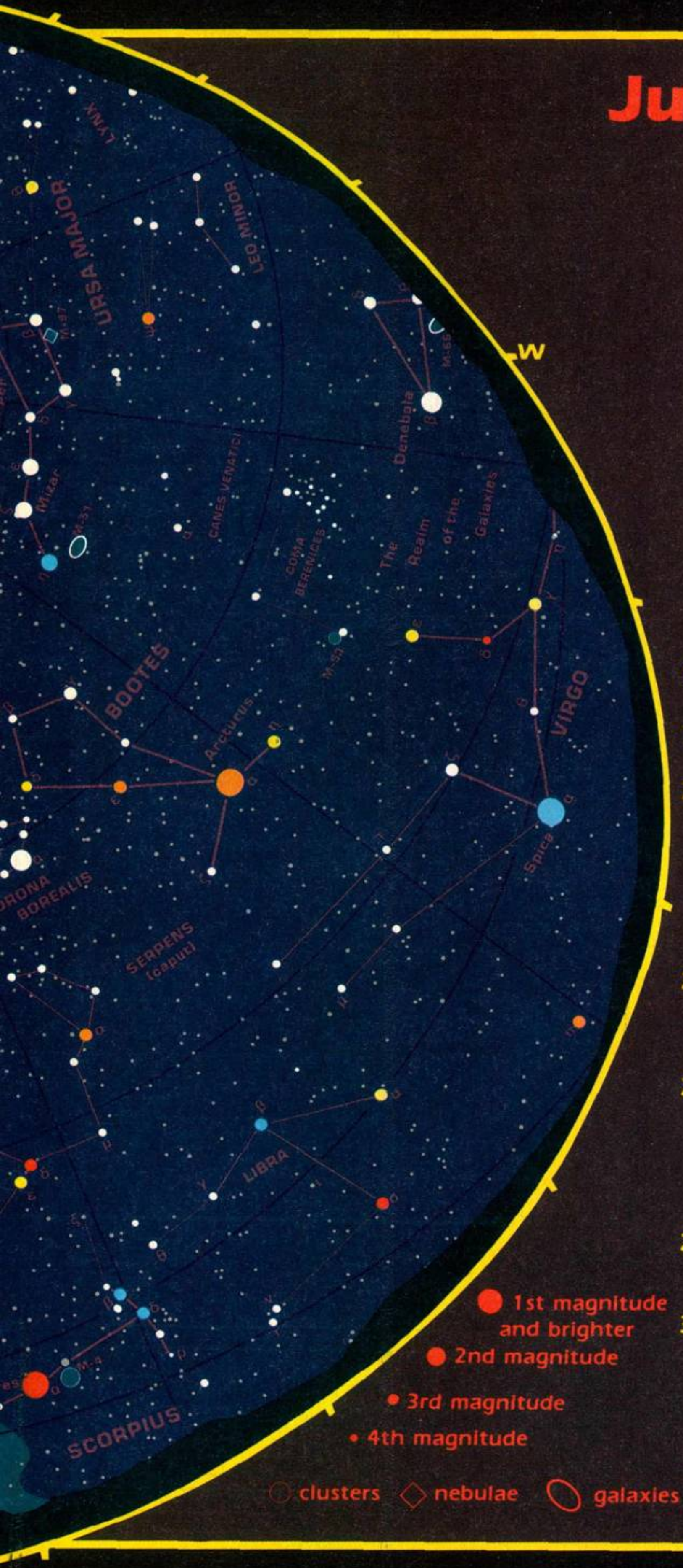
Mars passes its nodes fast enough to make occultations by the Sun infrequent and irregular. The Sun occulted Mars in 1966 and 1976, and will do so again in 1991 and 1998 — a bit more than one in seven of its superior conjunctions. And what could be the scientific value of such events? Admittedly little, but the November 25, 1976, occultation of Mars by the Sun provided Viking Project scientists with an interesting opportunity

Star Dome


N
E
S
CAMELOPARDALIS
CASSIOPEIA
ANDROMEDA
M-31
PEGASUS
LACERTA
CEPHEUS
URSA MINOR
Polaris
DRACO
AQUARIUS
Enif
M-15
EQUULEUS
DELPHINUS
Deneb
CYGNUS
Vega
LYRA
M-57
VULPECULA
SAGITTA
M-27
M-13
HERCULES
CAPRICORNUS
Altair
AQUILA
SERPENS
(cauda)
M-11
SCUTUM
OPHIUCHUS
M-17
M-22
M-20
M-8
SAGITTARIUS
M-6
M-7
Shaula
M-81
M-82

The Star Dome shows how the sky looks at:

11:45 p.m. on July 1
10:45 p.m. on July 15
9:45 p.m. on July 30


W
LYNX
URSA MAJOR
LEO MINOR
CANES VENATICI
COMA BERENICES
The Realm of the Galaxies
Denebola
Mizar
M-51
M-65
M-53
BOOTES
Arcturus
VIRGO
Spica
CORONA BOREALIS
SERPENS (caput)
LIBRA
M-4
SCORPIUS
● 1st magnitude and brighter
● 2nd magnitude
● 3rd magnitude
• 4th magnitude
○ clusters
◇ nebulae
⬭ galaxies

July Sky Almanac

2nd The Moon reaches perigee at 6:33 p.m. EDT: 228,229 miles.

3rd Earth is at aphelion around 3 a.m. EDT. We will then be 94.51 million miles from the Sun.

5th First Quarter Moon occurs at 5:04 p.m. EDT.

7th Tonight, the gibbous Moon will lie east of Saturn and north of Mars in Libra.

9th Rounder and more nearly full, the Moon will lie north of Antares near Uranus tonight (see Backyard Astronomer).

12th The Moon is Full at 10:20 p.m. EDT.

18th The Moon is at apogee at 9:37 a.m. EDT: 251,551 miles.

20th Mercury is at its greatest elevation for this apparition: look for it very low in the western sky about half an hour after sunset.

21st Last Quarter Moon occurs at 12:01 a.m. EDT.

26th Mercury and Regulus will lie less than a degree apart in the evening twilight — use binoculars.

28th The Moon is New at 7:51 a.m. EDT. Also today: in the predawn hours, look in the east for members of the southern Delta Aquarid meteor stream.

29th The crescent Moon will be passing near Mercury in the evening sky.

30th The Moon reaches perigee (for the second time this month) at 8:15 a.m. EDT: 225,159 miles.

to measure some important quantities — including how much the path of radio waves from the spacecraft was deflected by the curvature of space in the vicinity of the Sun's gravitational field.

July also makes for good meteor hunting. The Delta Aquarid shower peaks at the very end of the month. In dark skies, you may see as many as 15 of these meteors coming from a point near the star Delta (δ) Aquarii after midnight. You may have trouble distinguishing these moderate-speed meteors from the Capricornid shower, also active at this time of year.

The Starry Sky

The constellation of the Dragon, **Draco**, coils high in the north above the raised bowl of the Little Dipper, part of **Ursa Minor** the Little Bear. **Scorpius** the Scorpion threatens low in the south. Nestled between these two creatures are a monster-killing strongman (**Hercules**) and a serpent-holding giant (**Ophiuchus**). In the east beckon the brighter constellations of late summer.

In the northwest as darkness falls, the **Big Dipper** hangs from its 15°-long handle. A longer but much fainter line of stars now parallels the handle on the right, between it and the bowl of the Little Dipper. This line is the tail end of Draco; the entire pattern now forms a kind of vast floppy capital N. A pattern of four stars at the high end of the figure — a noose on the end of this long stellar strand — represents the Dragon's head. The stars are second-magnitude **Eltanin** (Gamma [γ] Dra), third-magnitude **Rastaban** (Beta [β] Dra), fourth magnitude **Grumius** (Xi [ξ] Dra) and nearly fifth-magnitude **Kuma** (the binocular double star Nu [ν] Draconis).

Turning to the south, we see two constellation giants head to head. The figure of Hercules is upside-down; his lower torso, higher in the sky, is the four-star figure called the Keystone. The rather inconspicuous Keystone lies midway between Corona Borealis and Vega; it is worth learning, for it holds the magnificent globular cluster **M-13**. The cluster is barely a glimmer to the unaided eye even on the best nights, but one cannot help feeling a thrill at knowing that it represents the combined glow of perhaps a million stars.

In the south, trace the full length of the Scorpion east from the row of stars in his head to his ruddy stellar heart of first magnitude and round the southern tail, tipped with a second-magnitude stinger. The southernmost part of Scorpius never rises as seen from Canada, but fortunately ruddy Antares lies farther north, at declination −26.5°. The Scorpion's stinger features the bright star called **Shaula**. Not far to the northeast are **M-6** and **M-7**, a pair of giant open clusters that can be seen with unaided vision in any dark sky. The clusters are loveliest in binoculars.

The widest part of the Milky Way, stretching from Scorpius across the Teapot asterism of Sagittarius the Archer, is still in the southeast, but the more northerly Summer Triangle is now prominently high in the east. **Vega**, the luminary of **Lyra** the Lyre, is the Triangle's brightest and westernmost member. Not far southwest of Vega is the solar apex — the direction in which we appear to be traveling through the Galaxy. A point a little to the northeast of Vega was the north celestial pole about 13,000 years ago (and will be again about as far in the future). Vega was a brilliant North Star as the last Ice Age waned.

Below Vega and Lyra is **Cygnus** the Swan, whose brightest stars form the asterism known as the Northern Cross. **Deneb** is the first-magnitude tail or top of the cross. **Albireo** (Beta Cyg) is the Swan's beak or the cross's base — the star **Sadr** forming the juncture of the crossbeams. The area around Sadr is especially star-rich, and the naked eye reveals a superb patch of Milky Way in this region. The patch is know as the Cygnus Star Cloud.

Another constellation bird is **Aquila** the Eagle, south of Cygnus. Its outstanding star is **Altair**, about midway in brightness between Vega and Deneb.

In Tim Hunter's unique portrait of the January 1984 ecliptic, faint Mercury appears in the red glow of the coming dawn. Higher still are Venus, Jupiter, the Moon, the star Antares in Scorpius, Saturn, Mars, and the blue-white trail of Spica in Virgo.

A bright Perseid meteor flashes near Deneb in the constellation Cygnus. Cygnus is high in the eastern sky by the time July twilight fades, but the peak of the Perseid meteor shower is still a month off. Gordon Moeller used 400-speed film and a 35mm lens set at f/2.

Although the Summer Triangle is itself more of an attraction than a pointer to other patterns, there is a fascination in connecting its bright stars and constellations with other stars. Notice that a line drawn from Altair through Vega comes close to the end star of the Big Dipper's handle. A right-angle turn then brings us almost straight to **Arcturus** (Alpha Bootis) in the west. If you draw a line downward from Vega through Deneb, it extends to autumn's **Great Square of Pegasus** rising in the east.

Skylore

The constellation we now call Hercules was known as such by the classical Greeks — but not in their early times. Many ancient writers refer to this pattern as the Kneeling One, apparently an unidentified character. It is tempting to think the Kneeling One was a hero from an earlier culture's legends, which the Greeks eventually replaced with their own.

The original character in our constellation Hercules may have been Gilgamesh, the greatest hero of Mesopotamian legend. The story of Gilgamesh may be the oldest dated tale of truly literary quality — a fragment of one version of the story goes back to around 2000 B.C. Some believe that the story sprang up even earlier still — perhaps as far back as 3000 B.C. Whenever and however the tale got its start, the story remains rich, inventive and of human significance even now, 5000 years later.

Gilgamesh was king of Erech (also called Uruk), a great Sumerian city in a time when civilization's greatest cities held no more than 30,000 or 40,000 inhabitants and the world was still very wild. The people of Erech admired their king and greatly valued his ability to protect them. On the other hand, they hated his appropriation of their daughters, lovers, and even wives for his amorous adventures. Such behavior could not be accepted even from a great king. No man could overcome Gilgamesh in battle, so the people prayed to their gods to send a person who could humble him.

The creative god responded by making from mud a man whose strength would be equal to or even greater than that of Gilgamesh. He was a great friend of the animals and would free them from the traps of Gilgamesh's hunters and roam freely with all the beasts. The wild man's name was Enkidu. When Gilgamesh heard what Enkidu was doing, the king devised a plan to tame him.

One of Gilgamesh's hunters took a courtesan from the city and left her in the fields to tempt Enkidu. The woman bared her bosom and awaited the wild man; Gilgamesh guessed rightly that the innocent Enkidu would not know how to resist her charms. After Enkidu had lain with the courtesan, she tried to coax him to come back to the city and abandon the animals. Even though Enkidu did not want to leave, he had little choice: whereas the wild animals had previously gathered around him in trust and affection, all now ran from the sight of him. In great despondency Enkidu followed the courtesan back to Erech.

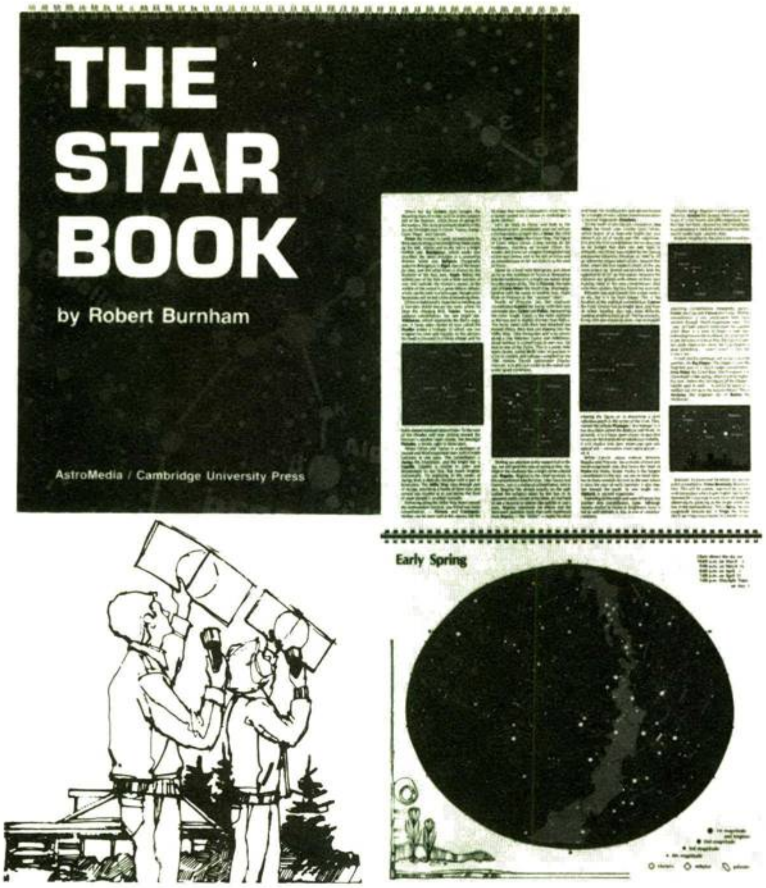
Perhaps Enkidu had lost some of his natural strength, but he still had enough left to meet the inevitable challenge — a wrestling match with Gilgamesh. To his amazement, Gilgamesh found that Enkidu was an opponent who could meet him hold for hold and strength for strength. Their match was a draw, and the two men became best friends. Gilgamesh became more interested in feats of adventure and heroism than stealing women, and the people were happy.

The exploits of Gilgamesh and Enkidu were mighty, but at last they faced a threat that even they might not be able to overcome. The people of Erech needed a new source of wood, and the stories told that the best was found on Cedar Mountain, a place 20,000 hours journey away from Erech. The immense length of the journey was not so great a problem as the guardian of the mountain — a terrifying creature called Humbaba. The people were afraid of losing their king, but Gilgamesh would not be denied and set off with Enkidu.

They finally arrived at the great forest of Cedar Mountain, and Gilgamesh shouted out his challenge to Humbaba. There was no response from the monster's lair. Enkidu became afraid — possibly because he feared destroying a guardian of nature. He still felt guilty about his own break with the nature he had once loved completely. Gilgamesh, as usual, would not listen but instead prayed to the gods for support and said he would attack in the morning.

The gods were with Gilgamesh, for in the morning when Humbaba, bellowing, huge, and hideous, rushed forth to defend his sacred spot, the battle was great — but Gilgamesh won. Enkidu then rushed in and chopped off the monster's head. Gilgamesh adorned himself to give praise to the gods. The wily, faithless goddess of love, Ishtar, was suddenly infatuated with him, but Gilgamesh repulsed her. Ishtar was furious and sent the Celestial Bull to attack Gilgamesh at Erech. But Gilgamesh and Enkidu were victorious again, and Enkidu cast the bull's bloody hide on the goddess with words of derision. For this, he earned Ishtar's fatal curse.

Enkidu once had a horrible dream about being taken forever to a place of darkness; now, after 12 days of sickness, his dream came true, and he died. Gilgamesh grieved and raged, but then he fled for the fear was on him that even though he was two-thirds a god, he was also one-third a mortal and must some day go to that dark, joyless place. What he did to try to save humanity from death involves us with a story much like that of Noah, with speculative identifications with many constellations. Next month, we will consider these matters and the conclusion of Gilgamesh's adventure.



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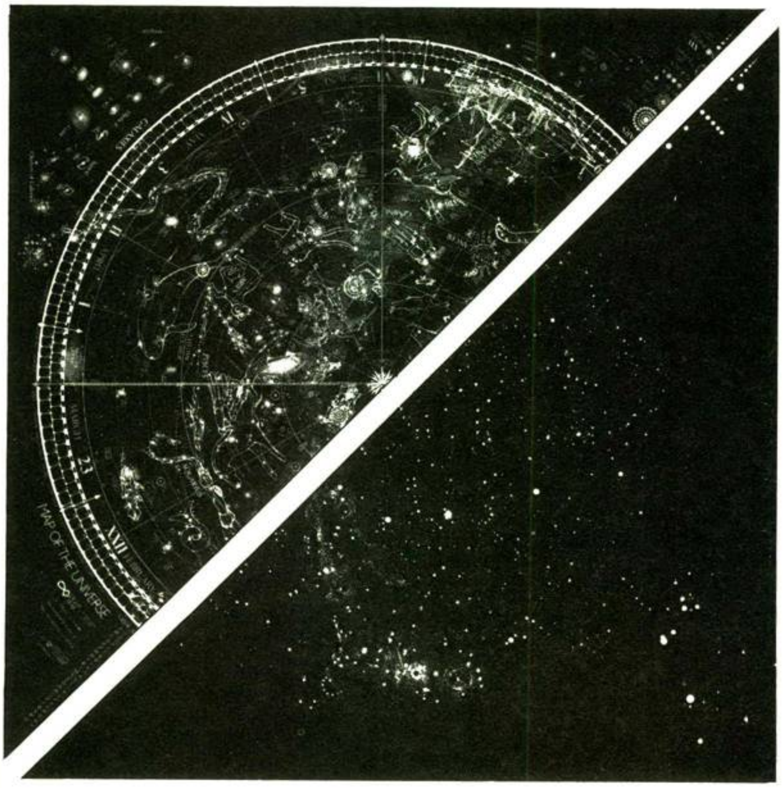

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Gazer's Gazette

Observing Nebulosities in Cygnus

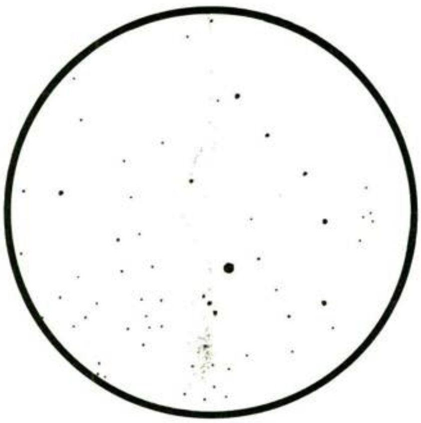
by Steven Bardwell

The constellation Cygnus is the "downtown" section of the summer northern Milky Way — an area so rich in faint stars that observers often lose their bearings when sweeping the region with finder telescopes. Although it is perhaps best known for its bright open star clusters and planetary nebulae, Cygnus the Swan is also home to a number of elusive emission nebulae. These gas clouds lie along the Orion/Cygnus Arm of the Milky Way, approximately 90° away from the direction of the galactic center, and consist primarily of ionized hydrogen gas excited into fluorescence by nearby hot young stars. But observing these clouds is not easy; you'll require a wide field of view and jet black skies, for their surface brightness — their luminosity per unit area — is abysmally low.

When you set out to hunt these objects down, keep a few characteristics in mind: a nebula's total brightness, its surface brightness, its spectral properties, and the surrounding area. Knowing about the complex relationships between these factors will help you estimate the visibility of these nebulae in your telescope and under varied observing conditions.

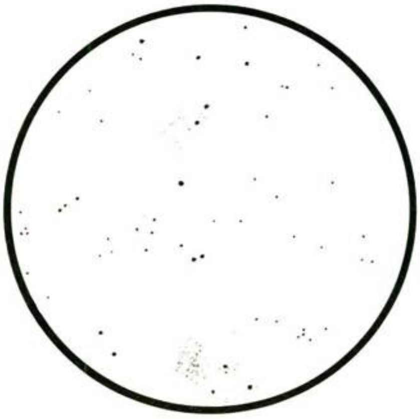
Total brightness, or integrated magnitude, is *not* a useful figure for extended deep-sky objects. This is because integrated magnitudes tell you how bright the object would be if all its light were concentrated into a point. But nebulae — except for a few planetaries — are not "stellar" objects. Their light is unevenly spread out over an area often many arc-minutes in diameter, causing individual parts to appear quite dim. Though many nebulae have a total brightness of fourth, fifth, or sixth magnitude, their low surface brightness makes them difficult for 6-inch and 8-inch telescopes unless skies are unusually transparent.

Sky quality is as important as telescopic aperture in hunting down nebulosities in Cygnus. To get the most performance from your telescope, drive about 30 to 50 miles outside the city before you set up to observe. This will alleviate most of a city's "light cone," which blots out all objects of low surface brightness. You must also choose especially transparent nights — those free from haze — to make the most of seeing these nebulae. And needless to say, do not try to find them when the Moon brightens the sky.



NGC-6960

Sketch by David J. Eicher
8-inch f/5 reflector 35x



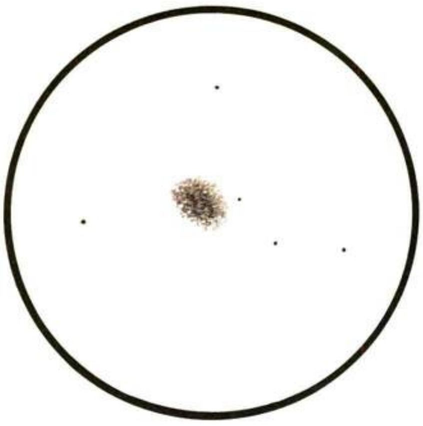
NGC-6992/5

Sketch by David J. Eicher
8-inch f/5 reflector 35x

Most emission nebulae emit light concentrated in only a few spectral lines. The Veil Nebula, for example, emits strongly in the green lines of doubly ionized oxygen. By using a filter that preferentially transmits those lines, the Veil Nebula is visible even in less-than-desirable skies. "Nebular" filters come in many types and sizes, and can make a big difference in how these objects appear. In some cases, especially in suburban locations, filters show objects that are invisible without them.

A couple of useful vision tricks help further in observing faint regions of nebulosity. The first is averted vision — looking to the side of the telescope's field rather than directly at the centered object. This utilizes your eyes' rods, photoreceptors that are markedly more sensitive to faint light than the cones, which are found in the center of your retina. The second technique, field sweeping, takes advantage of the fact that it is often easier to spot an elusive target if it moves. Gently rocking the scope back and forth around the area of a suspected object will help to reveal it.

When you look for large nebulae, always start with a low-power eyepiece. This will give you nice bright images and will make finding the correct position — either by star-hopping or using setting circles — relatively easy. After you find the nebula in question, you may want to change the eyepiece to increase the scope's magnification, but low-power, wide-field views will generally work best with large, dim objects.



NGC-7027

Sketch by Alan Goldstein
4-inch f/15 refractor 186x

The Veil Nebula

One of the finest nebulae in Cygnus is the Veil Nebula, a giant loop of ionized hydrogen and other elements blown off from an ancient supernova explosion. The complex spans several degrees and is spherical; although we see it as a loop due to an effect of perspective, it is actually a bubble. This object's delicate filamentary structure is unequaled in the north celestial hemisphere — strands of illuminated gas twist and turn every which way, suggesting a braided structure and giving the nebula its name.

On nights of excellent transparency, the two main segments of the Veil Nebula appear in 7 x 50 binoculars as thin, wiry streaks of greenish light. The eastern section, NGC-6992/5, is the brighter; it shows more detail than its westerly counterpart, NGC-6960 (which is bisected by the fourth-magnitude star 52 Cygni). To get a better look at the Veil Nebula, you'll need a wide field of view but considerably more aperture than binoculars afford. With a 4-inch f/4 scope under dark skies, the Veil becomes magnified enough to show some detail — an uneven, mottled texture pervades the wisps of light. An 8-inch telescope collects enough photons to show the Veil in great detail, providing the telescope has a low focal ratio and wide field of view. (Schmidt-Cassegrain owners may wish to use a focal reducing lens to halve their focal ratios and double their fields of view.) Large telescopes — in the 16-inch to 20-inch range — show a picture so intricate that it is difficult to sketch.

More challenging than the two primary sections of the Veil is the faint nebulosity in the middle of the bubble. The brightest part is NGC-6979, a little S-shaped patch of weak light northwest of NGC-6992/5. Faintly visible in an 8-inch scope, it appears mottled with uneven texture in larger telescopes. Closer to NGC-6960 is a large triangular nebulosity whose filamentary structure, when viewed in large scopes, is reminiscent of the crisscross pattern of ratlines in the rigging of sailing ships.

Nebulae Near Deneb

At magnitude 1.3, Deneb (Alpha [α] Cygni) is the brightest star in Cygnus and one of the members of the Summer Triangle — the others are Vega in Lyra and Altair in Aquila. Surrounding Deneb is a fascinating group of nebulosities, the largest and brightest of which is the North America Nebula, so called due to its resemblance to the North American continent. Also known as NGC-7000, the North America is so large and bright, and has such sharp boundaries along the "Gulf of Mexico" and "Hudson Bay," that it is visible — with averted vision — to the naked eye. In binoculars, the North America Nebula is one of the most fascinating objects in the sky. The combination of spectacular starfields in the Milky Way around Deneb, the dark clouds of the "Gulf of Mexico," the brilliant blue-white of Deneb, and the eerie glow of the nebula is breathtaking. In the same binocular field, part of the Pelican Nebula (IC 5067) also appears under dark skies, although it is much dimmer. With careful examination, two lobes of the Pelican Nebula can be distinguished, symmetrically arranged on either side of a line connecting the two bright stars 56 and 57 Cygni.

Through an 8-inch f/10 telescope, observing a trace of either the North America or Pelican Nebulae becomes more of a challenge because of smaller fields of view. The small open star cluster NGC-6997, which appears to be inside the North America Nebula, serves as a good landmark for finding the nebula's brightest portion. About 15′ south of the cluster is the coastline of the "Gulf of Mexico," where a dark cloud provides the easiest telescopic view of the nebula. On a good night you can follow the boundary north and south of the "Gulf" for some distance, although the contrast fades back to the level of the Milky Way.

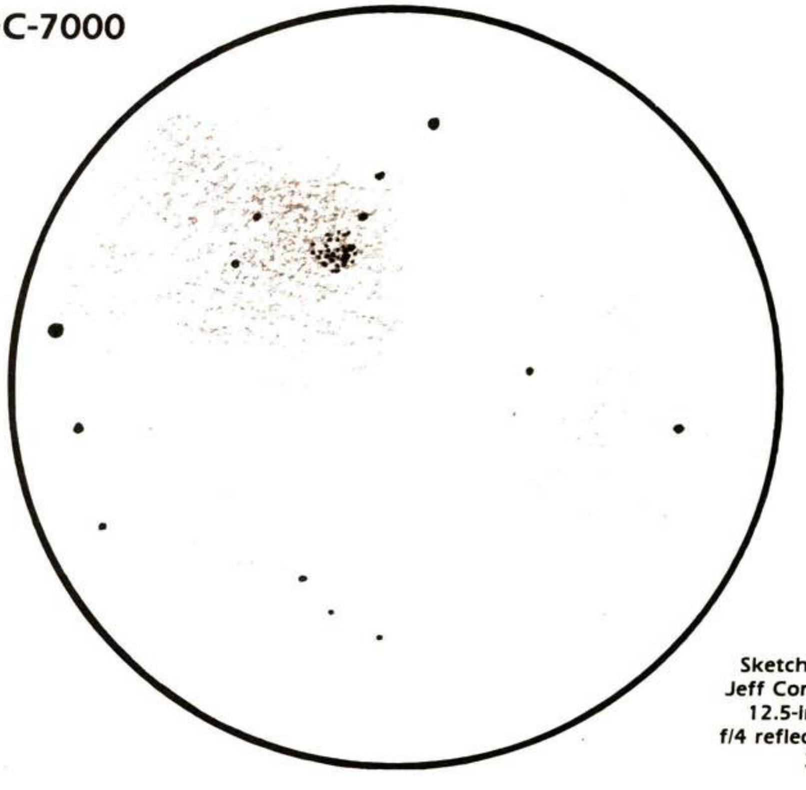
Just south of this area, and apparently part of the same complex of nebulosity, is a third object — IC 5068. This nebulosity is roughly as bright as the Pelican Nebula. Photographs of the region show considerable structure throughout the whole nebulosity surrounding Deneb, but IC 5068 appears in a moderate telescope as a featureless haze.

The Gamma Cygni Nebulosity

Sadr (Gamma [γ] Cygni), a magnitude 2.2 star, marks the center of the Northern Cross and hosts a large collection of faint nebulosities. The brightest of these is NGC-6888, sometimes called the Crescent Nebula, one of a handful of observable supernova remnants, and clearly visible as a small fuzzy patch in binoculars on very good nights. Its brightest parts are just visible in an 8-inch scope; on nights when the Veil Nebula is very impressive, NGC-6888 appears as a graceful arc seeming to connect the bright stars in the field.

IC 1318 is a large, irregular complex of nebulosity completely surrounding Sadr. It contains many individual nebulosities — all with the same catalog number. Six

NGC-7000



Sketch by
Jeff Corder
12.5-inch
f/4 reflector
35x

The Nebulosities of Cygnus

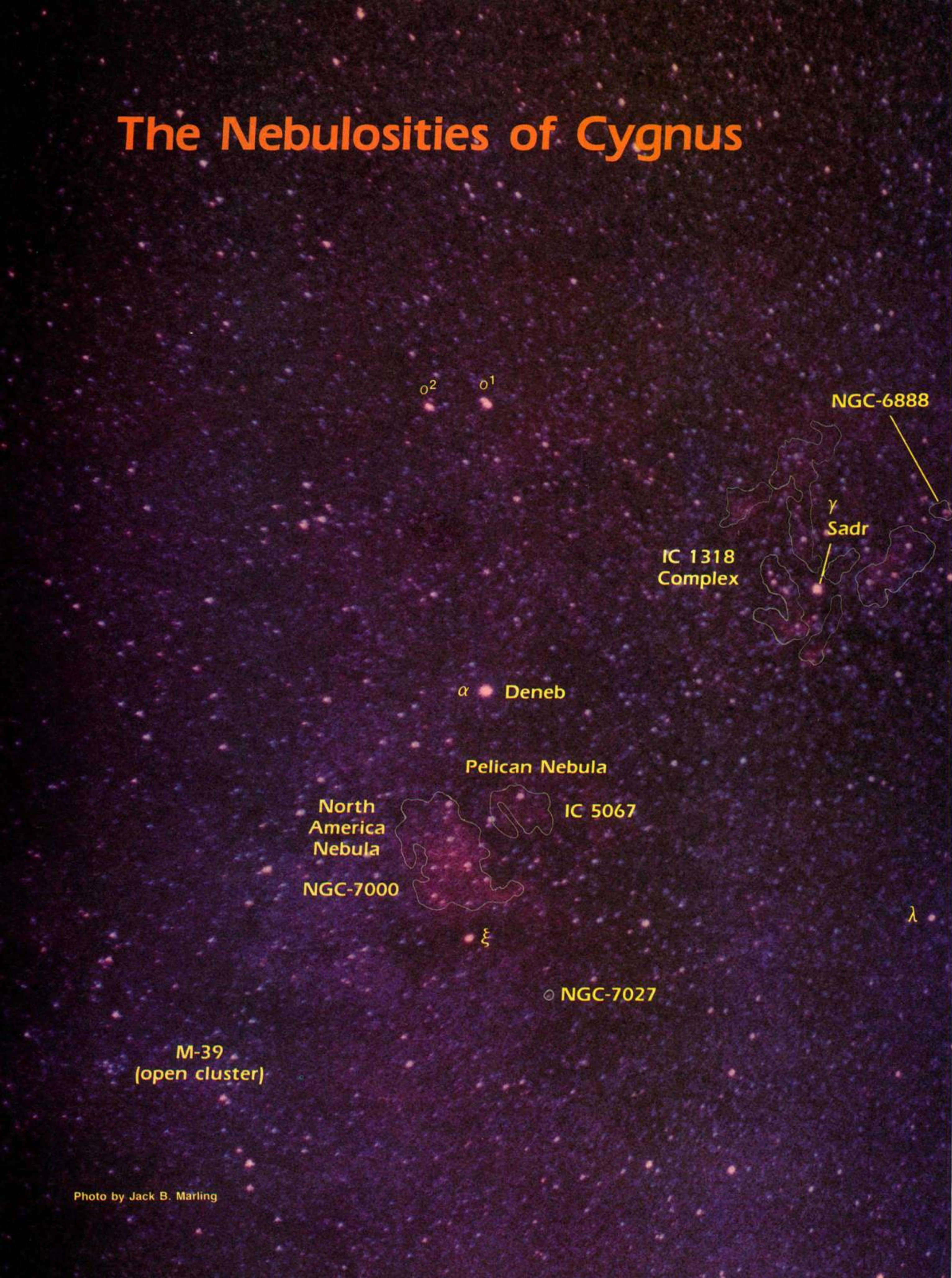
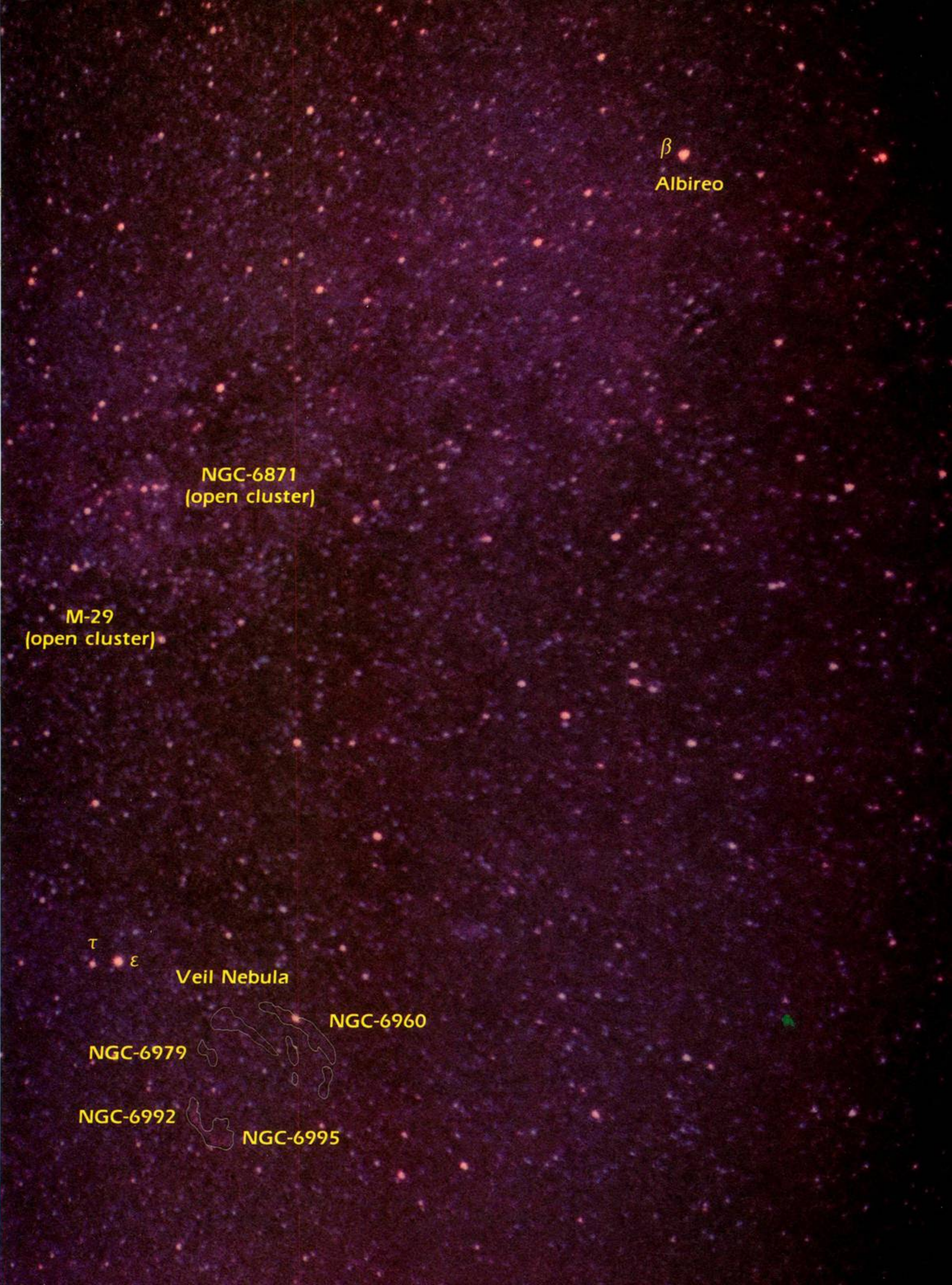
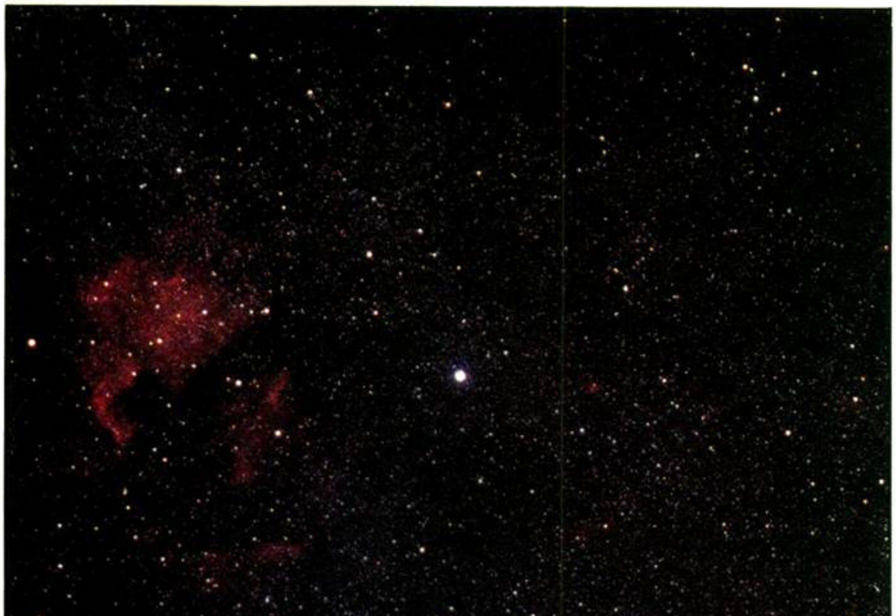

o^2
o^1
NGC-6888
γ
Sadr
IC 1318
Complex
α
Deneb
Pelican Nebula
North
America
Nebula
IC 5067
NGC-7000
λ
ξ
NGC-7027
M-39
(open cluster)

Photo by Jack B. Marling


β
Albireo
NGC-6871
(open cluster)
M-29
(open cluster)
τ
ε
Veil Nebula
NGC-6960
NGC-6979
NGC-6992
NGC-6995



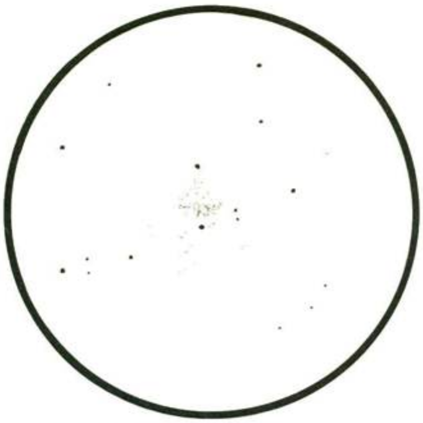
The region of Deneb (Alpha [α] Cygni) and Sadr (Gamma [γ] Cygni) holds the most spectacular of the Swan's nebulae. Near Deneb lie the North America and Pelican Nebulae; surrounding γ Cyg is the complex known as IC 1318. Photo by Jack B. Marling.

Nebulosities in Cygnus

Object	Type	R.A. (2000)	Dec.	Mag.*	Size
NGC-6888	SNR	20h12.5m	+38°25′	7.4	18′ x 12′
IC 1318	☐E	20h16.5m	+41°48′	2.3	24′ x 17′
IC 1318	☐E	20h18.8m	+40°39′	2.3	50′ x 25′
IC 1318	☐E	20h19.8m	+40°07′	2.3	45′ x 25′
IC 1318	☐E	20h23.8m	+40°45′	2.3	85′ x 50′
IC 1318	☐E	20h28.5m	+39°57′	2.3	70′ x 20′
NGC-6960	☐E	20h45.6m	+30°43′	—	70′ x 6′
IC 5067	☐ER	20h48.6m	+44°22′	1.3	85′ x 75′
NGC-6979	☐E	20h49.9m	+32°02′	—	40′ x 20′
NGC-6992/5	☐E	20h56.4m	+31°42′	—	78′ x 8′
NGC-7000	☐ER	20h58.8m	+44°20′	1.3	120′ x 100′
NGC-7027	☐B	21h06.9m	+42°14′	17.1	18″ x 11″
IC 5146	☐R	21h53.2m	+47°16′	10.0	12′ x 12′

Mag.* = magnitude of illuminating star SNR = supernova remnant

☐E = emission nebula; ☐R = reflector nebula; ☐B = bipolar nebula.



IC 5146

Sketch by David J. Eicher
8-inch f/5 reflector 100x

parts of this complex are visible in amateur instruments. Two of them are involved with open star clusters: NGC-6910, a small Y-shaped group, appears to have streamers of faint gas off to its east, and the cluster IC 1311 seems to illuminate a dim segment of nebulosity.

The southeastern component of IC 1318 is illuminated by an eighth-magnitude star, making it visible in an 8-inch scope. Its southern border is sharply defined and shows several dark lanes along its edge. But this section of the nebula lacks detail in medium-sized instruments; it is featureless. IC 1318's parts to the south are even more elusive.

Other Cygnus Nebulosities

Cygnus the Swan holds seven other nebulosities within reach of amateur instruments. Two of these are well-known: the first is the unusual emission object, sometimes classed as a planetary nebula, NGC-7027; the second is IC 5146, the Cocoon Nebula. NGC-7027 is one of the brightest examples of color in a nebula, appearing a strong blue-green. It is a small object, and stands up to high magnification due to its high surface brightness. At the other extreme is 5146, a large faint reflection nebula whose superimposed dark lanes resemble those of the Trifid Nebula (M-20) in Sagittarius. IC 5146 lies at the end of a wide dark lane chopping through the Milky Way; with an 8-inch telescope, the dark lane is striking but the nebula is exceedingly faint.

Remember to wait for a crisp, dark night to go hunting for the nebulosities of Cygnus. If you use a wide field eyepiece and techniques like averted vision and field sweeping, you'll get a satisfactory view of these ghostly clouds of ionized gas. But don't be discouraged if the nebulae elude you for some time; indeed, they are among the more difficult deep-sky objects the sky has to offer.

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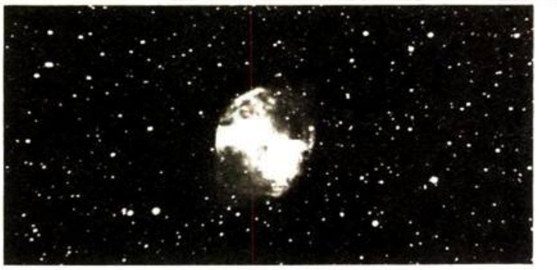

The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

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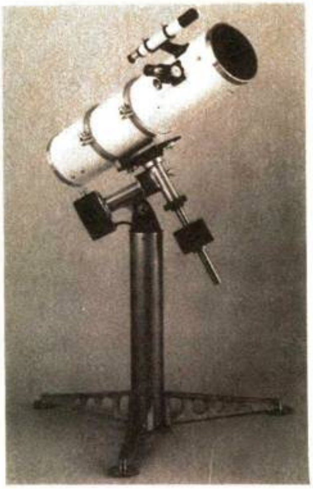

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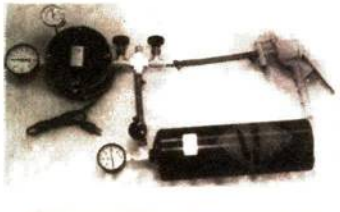

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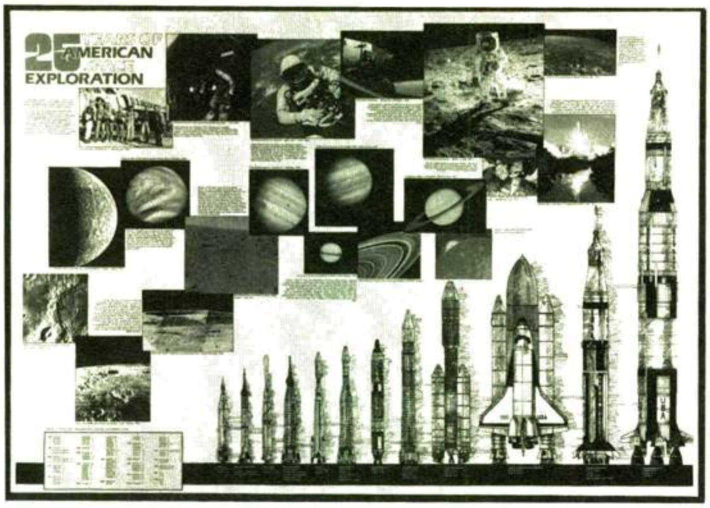

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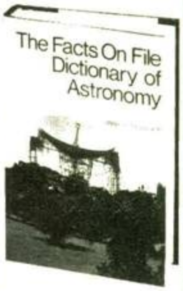

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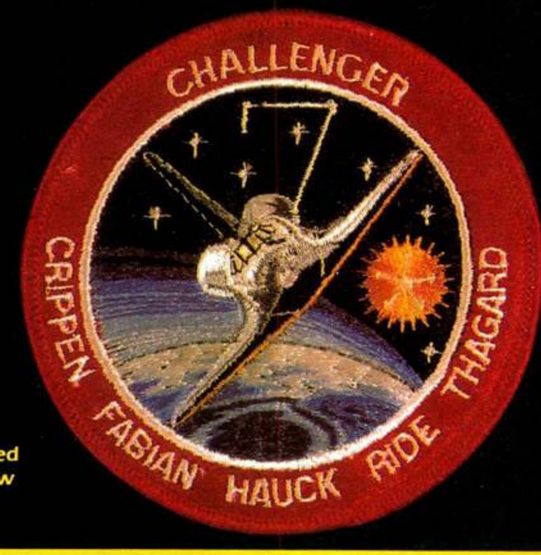
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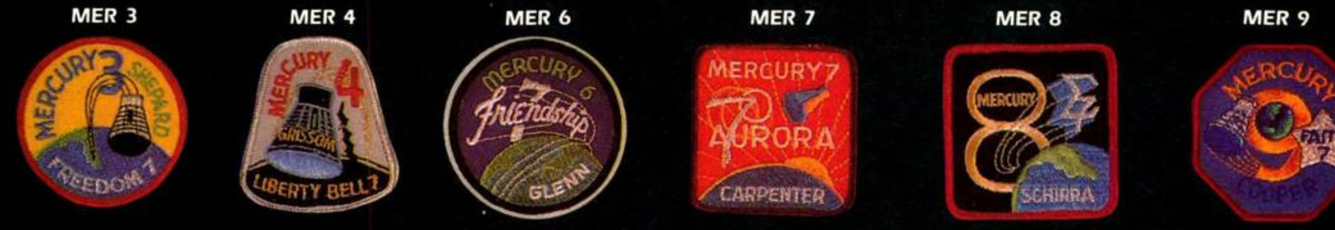
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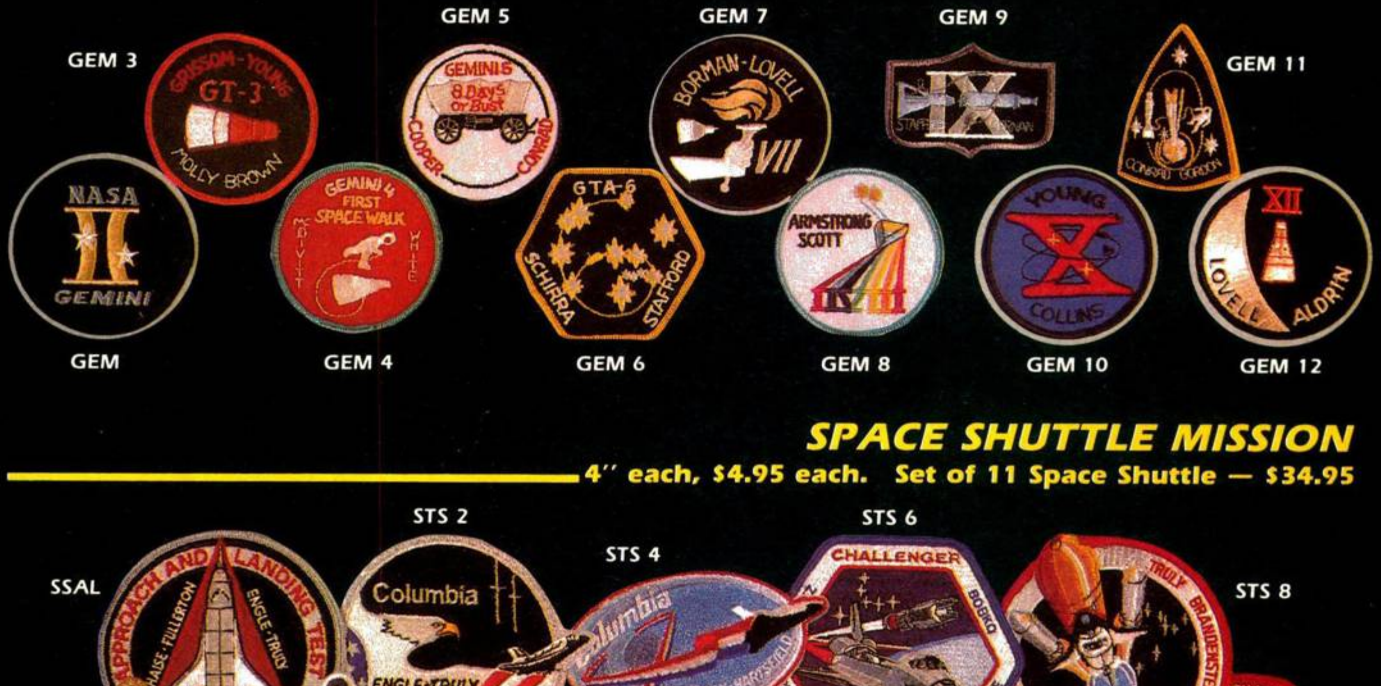
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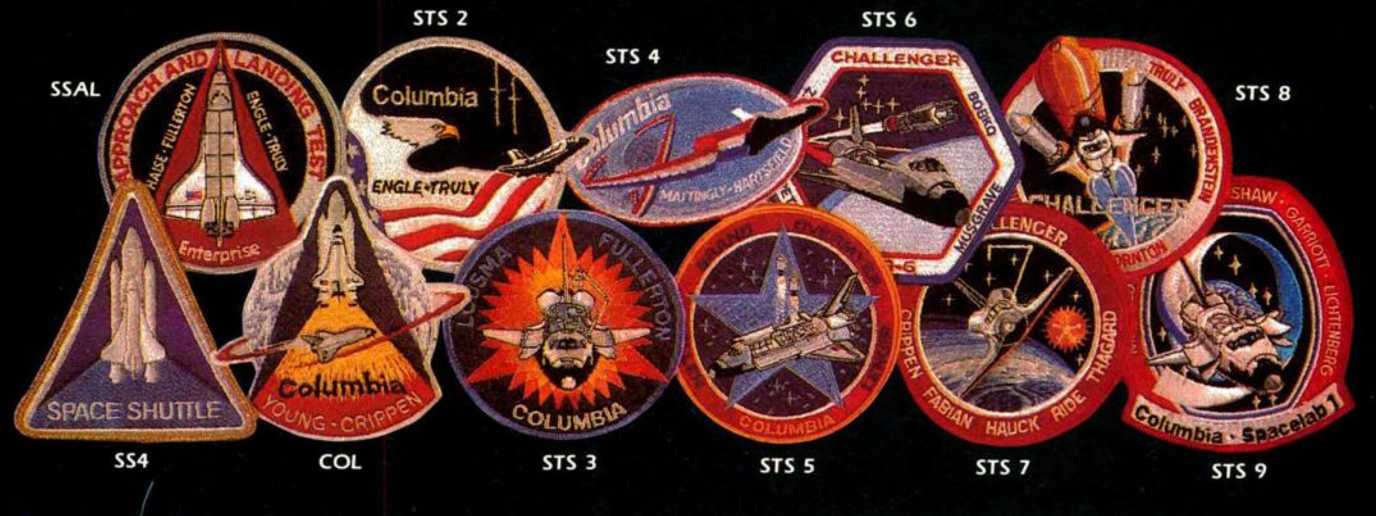
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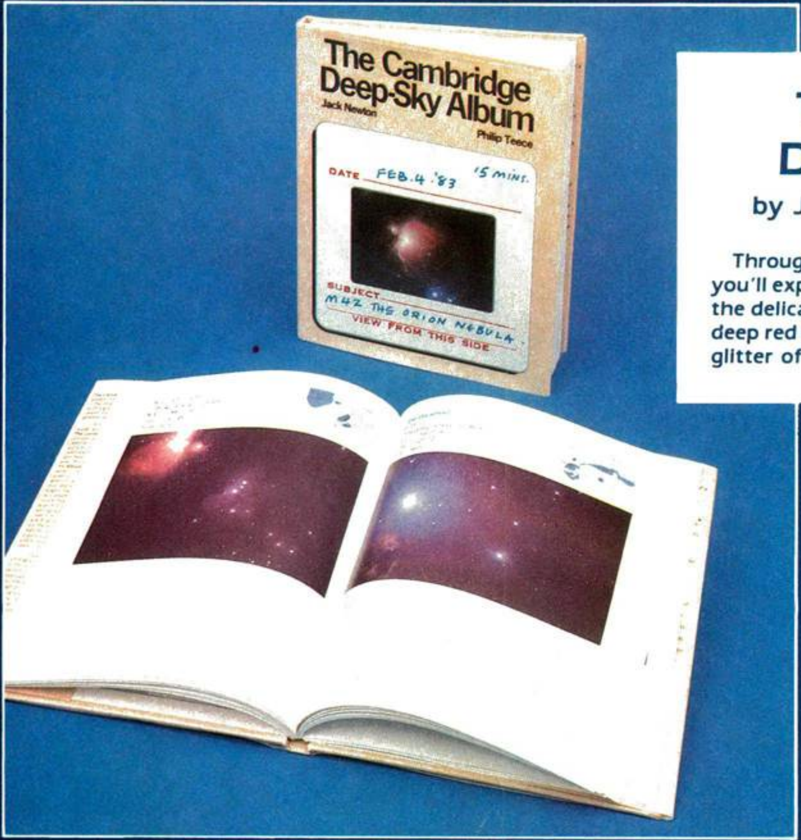

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by Jack Newton and Philip Teece

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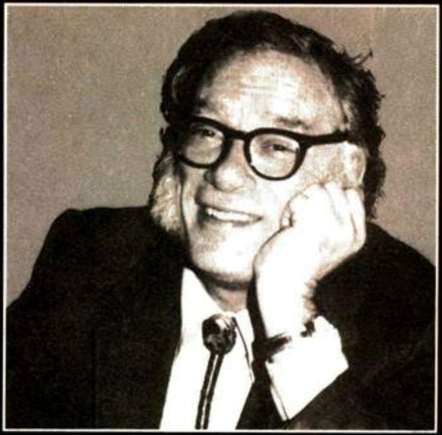

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ASTRO NEWS

Space Station Politics

"America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned Space Station, and to do it within a decade."

With these words, part of the strongest statement of support NASA has received from any chief executive since John Kennedy, President Ronald Reagan committed the United States to its next major goal in space. The statement appeared all the stronger for being in the middle of a State of the Union address otherwise remarkably vague and noncommittal.

Financial support, however, was only partially forthcoming. The administration's new budget includes only some $150 million of the $235 million NASA originally requested for Space Station development; funding for the space tug — considered by NASA essential to effective Space Station operations and called an "orbital maneuvering vehicle" in its latest incarnation — was canceled outright. But if NASA does manage to herd the eight-year project through Congress and a minimum of two administrations, it will obtain a facility of unprecedented versatility and potential. (See "Space Stations: The High Frontier," ASTRONOMY, June 1984.)

President Reagan also directed NASA to encourage participation by Europe, Japan, Canada, and private industry in construction and use of the Station. Germany and Italy, in a study they call Columbus, and the European Space Agency as a whole, are studying ways to use Spacelab components in the Station and a space tug. Canada wants to find room for their remote manipulator arm, and Japan wants to do research.

In supporting the Station, Reagan overrode the negative advice offered by several parts of the government, including the Office of Management and Budget and the Defense Department. Caspar Weinberger bitterly opposed the Space Station, even to the extent of complaining directly to NASA Administrator James Beggs after Reagan's speech. But although the Air Force and Navy claim to have no need for a Space Station, they will not oppose it.

Now that the Space Station has faced opposition from virtually the entire administration and survived, it must face Congress. Its survival there is uncertain.

Tim Kyger, 18th Assembly delegate to last summer's California State Democratic Convention and a member of the L-5 Society's Board of Directors, recently pointed out that it is not generally realized how political an issue space is. Apollo was definitely a Democratic project, initiated by Kennedy and supported to maturity by Lyndon Johnson. The projects designed to follow up on Apollo were stopped by Richard Nixon, a Republican. Nixon replaced Apollo with the Space Shuttle, establishing it as a Republican program — and the Shuttle was a project that Jimmy Carter, a Democrat, tried his best to starve. He failed, largely because the Department of Defense had in the meantime become dependent upon the Shuttle for launching its satellites.

President Reagan has now established the Space Station as a Republican project. What this will mean in a Congress controlled by Democrats is far from clear. Congress as a whole has always been more sympathetic to NASA's wishes than any President has. But it is the nature of our government that only the executive branch may effectively set goals and initiate the projects required to achieve them. Democratic opposition has been present, but muted so far.

What will this mean come November? At this point it seems likely that Walter Mondale will be the Democratic candidate — and he has been second only to Senator William Proxmire in his opposition to space spending. On the other side, Reagan appears to have found his abiding interest in civilian space development only recently — it took him three years in office and what looked like the possibility of facing John Glenn in a presidential campaign.

Perhaps most surprising of all, the strongest opposition to date has come from within the space community itself. William W. Winpisinger, president of the International Association of Machinists and Aerospace Workers, whose members would clearly benefit by a renewed space program, was quoted in the *New York Times* as saying "It's lunacy." Apollo veterans are arguing that a lunar base would have been a better goal, pushing us beyond what we have already done and forcing development of a Space Station as well. The planetary scientists are also upset; they see Station development as a project that will drain away funds from unmanned missions.

Eric Drexler, writing in the *L-5 News*, has argued that the Space Station could be built for a small fraction of the cost NASA says it needs. NASA, Drexler argues, is planning the Station with a lot of unnecessary new technology. But with a crew on hand to correct problems as they arise and with weight being a positive advantage in combating atmospheric drag — the Station is planned for low Earth orbit — the Station should not need the reliability or weight-saving efforts that make most space projects so expensive.

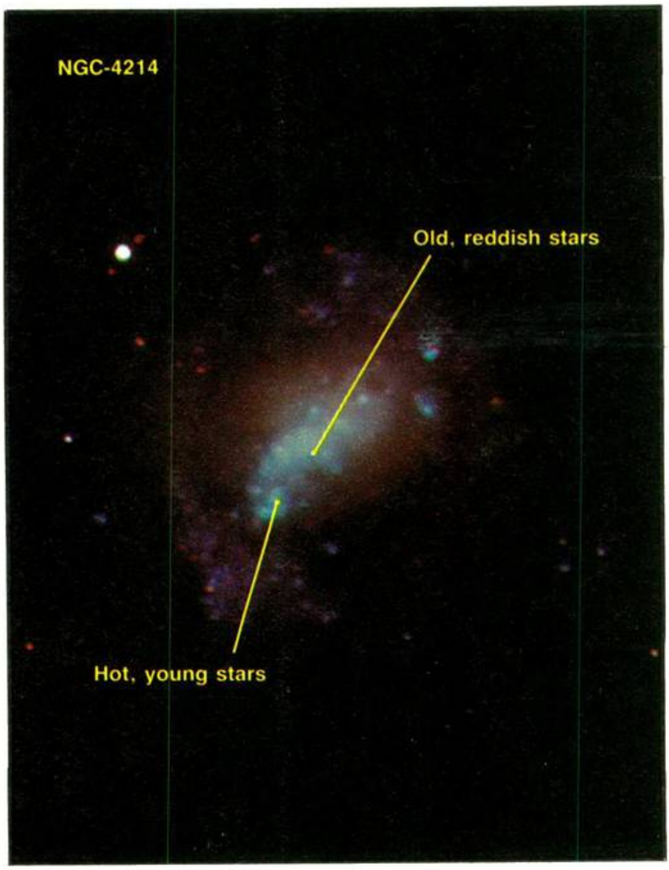
Nevertheless, the Space Station *is* in the budget and NASA may be expected to fight as if its very survival depended upon keeping the project alive. Given that NASA wants to be more than just a launch vehicle operator, this may well be true. And new technology seldom goes to waste: the new developments NASA wants are just those needed for future projects.

This is what is most important to NASA's future — and far more important than the success or failure of this year's Space Station initiative. NASA is no longer hiding its long-term plans, but is openly talking of its new project as the first step toward a lunar base and a manned missions to Mars. *Donald F. Robertson.*

NGC-4214: Old Stars and New

A photograph of NGC-4214 shows a patchy and irregular distribution of individual stars. Its appearance is similar to the Large Magellanic Cloud, where astronomers have found the individually resolvable stars to be the brightest young red and blue supergiants. Regionally, such young stars may clump together to form clusters of hot stars mixed with gas and dust. (The Orion Nebula is a local example.) The brightest dozen or so objects to the left and below the center of NGC-4214 are clusters of hot young stars still mixed with and still illuminating the remnants of the clouds from which they formed.

Studies of the Magellanic Clouds have shown that in addition to the swarms of young stars and clusters, an older and more smoothly distributed population of stars also exists. Stars of the older stellar population, however, are not so bright that they can be seen individually, and a galaxy's old population tends to look like a diffuse distribution of reddish stars. In the photo of NGC-4214, these show up as slightly offset from the complex of bright knots, which are



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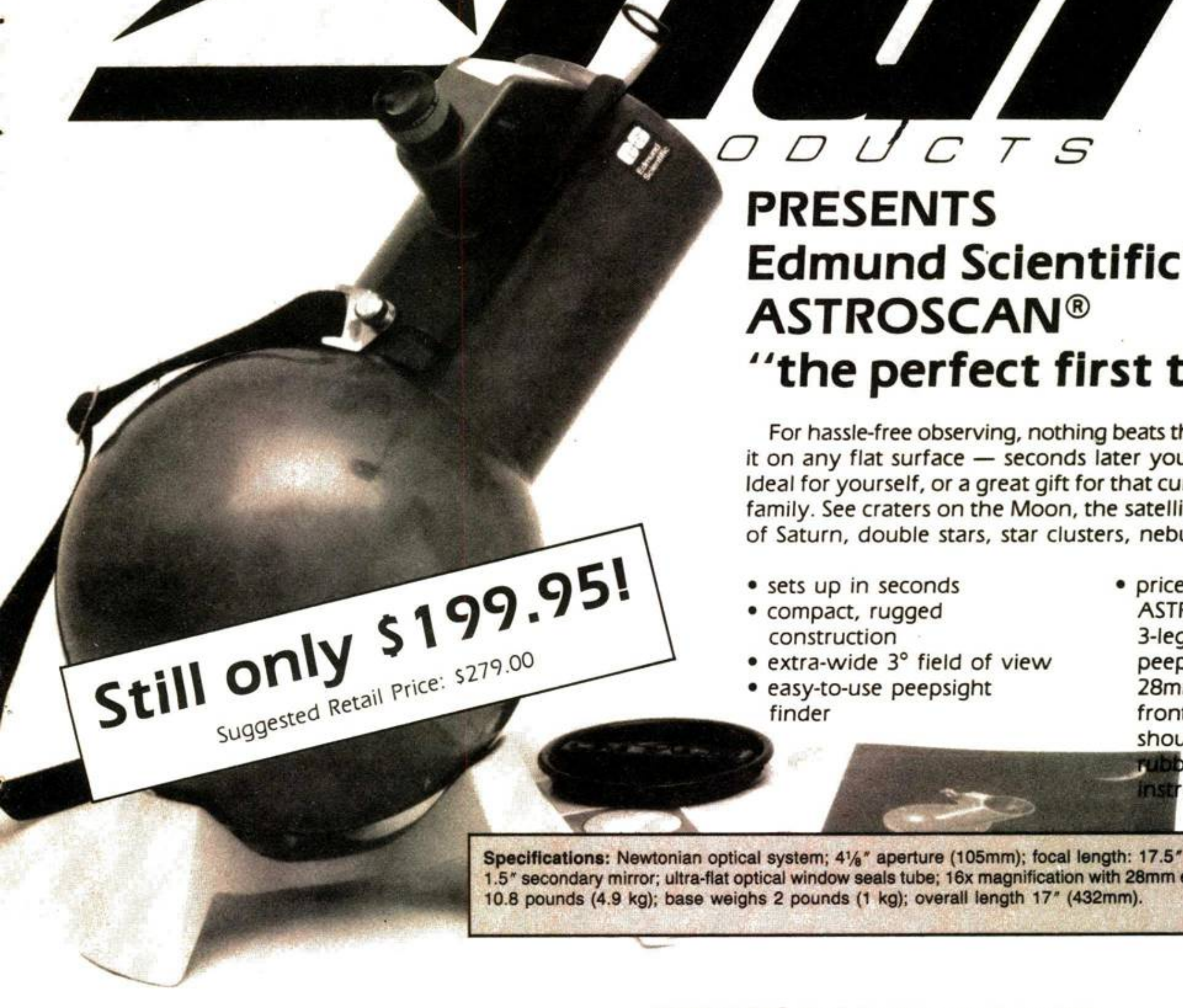

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the emission nebulae associated with the young stars.

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All About Telesto

A previously unknown satellite of Saturn, now officially named Telesto, was identified and photographed by researchers at the Lunar and Planetary Laboratory at the University of Arizona in Tucson in April 1981. After analyzing data provided by five images made of the "new" satellite, researchers have finally charted Telesto's precise orbit.

The satellite was discovered during extended observation and imaging of Saturn's faint E ring when the Earth was 5.4° above the ring plane and the phase angle was 0.7°. Astronomers took photographs of the E ring and the satellite on hypered 2415 combined with a focal-plane coronagraph operating at f/6 on the Laboratory's 154-centimeter Catalina Observatory reflector.

"In 1966, we took some marginal pictures that suggested the E ring existed," says John W. Fountain, research assistant at the Lunar and Planetary Laboratory. "To verify the E ring, we needed some better images."

To get high-contrast, fine-resolution images, the researchers had to reduce the exposure time to minimize atmospheric seeing problems and reciprocity failure of the film. They also needed observing conditions that would reduce the large amount of scattered light from Saturn. When Earth lies close to the ring plane, scattered light is reduced and the visibility of the E-ring enhanced.

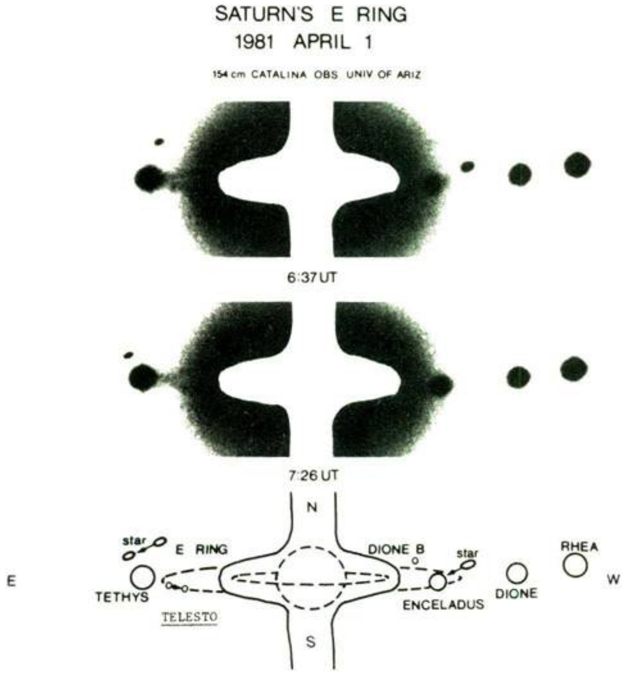
The focal-plane coronagraph uses an occulting disk and an apodizing mask to reduce diffraction and scattered light in the instrument. The coronagraph was designed for use with either a charge-coupled device (CCD) or high-resolution film.

"Saturn is a very bright planet, and we are looking at a very faint object," Fountain explains. "If we did not use some kind of masking technique, the scattered light from the planet would wipe out what we were trying to observe. Additionally, the coronagraph uses a lens to image the entrance pupil of the telescope, then that image is masked to cut out the diffracted light. We then re-image the masked image onto film."

Normally, a 30-minute exposure would be called for, but to reduce it, Fountain hypersensitized the film by baking it at 130° F for 10 hours in an atmosphere of 8% forming gas (8% hydrogen/92% nitrogen). Hypering cut exposure time to about 10 minutes and researchers were able to record images of background stars as faint as magnitude 19.

The film images were then digitized: "It's not as important for us to 'see' a picture of an object as it is to recognize it is there," says Fountain. "We seldom analyze film because it is difficult to plot changes and calculate an orbit by positioning crosshairs on a fuzzy, grainy object. However, if we have an image on film, we can digitize the information and determine precise orbit and orbit changes."

Using this method, the researchers discovered that Telesto was 60° ahead of a known satellite, Tethys, and that it regularly oscillates 2° about its mean position.



Planetarium Sues Spitz

Idle for five years, the nation's second largest university planetarium is still waiting for its advanced computer system to become operational. The doors of the $1.5 million Arnim D. Hummel Planetarium at Eastern Kentucky University remain closed, with little hope for it to become operative in the near future.

The Commonwealth of Kentucky and the university have brought a $2.4 million lawsuit against the designer of the trouble-plagued projection system, Spitz Space Systems, Inc., of Chadds Ford, Pennsylvania, for breach of contract and punitive damages.

Eastern was to be the fourth planetarium in the nation to receive the "Space Transit Simulator" system. Like many planetariums, this system has the ability to recreate the skies at any point in Earth's 26,000-year "precessional cycle." The university's planetarium also is able to project each planet independently to create the illusion of space travel up to 100 astronomical units away from the Earth — something a traditional planetarium can't do. Purchased at the unit price of $952,000, the planetarium was to take about 15 weeks to install, with a completion date of August 31, 1978. But, according to planetarium director Jack Fletcher, "The company has not yet made it do everything that it is supposed to do."

Fletcher and his staff of five have been preparing programs that will be used once the planetarium is completed and opened. All the necessary programs, special artwork, and scripts have been prepared, but they are useless until the projection system becomes operational.

In January of 1982, the university hired Lee Simon, director of the California Academy of Science's Morris Planetarium in San Francisco, to determine if the system was functional and whether it had met the contractual agreement. Simon agreed that the university had not gotten what it had paid for; the planetarium was below specifications.

Planetariums in San Diego, California, St. Paul, Minnesota, and Cleveland, Ohio, have received the same system. Leonard Skolnick, president of Spitz Space Systems, said that those institutions and eight others in foreign countries are operating smoothly. Skolnick feels that the problem with the system rests with the officials at Eastern. "We have offered to go in and show that the system works," Skolnick said, "but for some reason they don't want us there."

Charles Whitlock, executive assistant to the president of the university, disputed Skolnick's claim that the blame could be attributed to Eastern officials. "We are confident that we have given Spitz every opportunity to make the system work," Whitlock said. He feels that the main objective of the university is "to make the planetarium operational."

Eastern's Board of Regents plans to do just this. It applied for state funds to replace the Spitz system. Fletcher said that at the time the system was installed it was unique. But since that time, other companies have created similar systems, which could replace the present one at Eastern. "If the university receives the state funds to replace the Spitz system," Whitlock said, "any money received from the suit would be used to repay the state."

The purpose of the planetarium is to serve all academic areas of the university with its multi-media capabilities. The planetarium will also serve public schools in eastern and central Kentucky and will be open to the general public several evenings a week. "This has been very disappointing for my staff," Fletcher noted. "We came to Eastern with the purpose of running this planetarium and we haven't had a chance to show what we can do."

Officials at the university have been unable to predict when the suit will come before the courts, but assume that the case will appear on the 1984 court calendar. Until then, the plush seats of Hummel Planetarium will remain empty.

Mike Savage.

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Convention of the Mid-States Region of the Astronomical League, Washington University, St. Louis, Missouri. Contact: Stephen Best, Convention Chairman, 6943 Amherst Ave., University City, MO 63130.

June 30
Northeast Regional Astronomical League Convention, Sperry Observatory, Cranford, New Jersey. Sponsored by Amateur Astronomers, Inc. Contact: Roger Tuthill, (800) 223-1063 (toll-free).

July 7-12
Joint Meeting of the Astronomical Society of the Pacific, the Western Amateur Astronomers, and the Astronomical Association of Northern California, University of California, Santa Cruz, California. Contact: Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

July 10-14
Case for Mars II, Boulder, Colorado. A workshop on the future of manned missions to Mars, sponsored by the Mars Institute of the Planetary Society, the Boulder Center for Science and Policy, and the University of Colorado Space Interest Group. Contact: Case for Mars, P.O. Box 4877, Boulder, CO 80306.

July 12-14
Microcomputers in Astronomy II, Fifth annual IAPPP-Fairborn Symposium, Fairborn, Ohio. Contact Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

July 16-24
Florida Spaceweek '84. State-wide celebration of the 15th anniversary of the Apollo 11 Moon mission. Contact: Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

July 16-August 3
Astronomy Institute for Pre-College Teachers, Austin, Texas. Contact: Mary Kay Hemenway, Department of Astronomy, University of Texas, Austin TX 78712. Phone (512) 471-4461.

July 20-31
International Workshop on Astrophotography, Oteppe, Belgium. Limited to young amateur astronomers ages 16-24. Contact: Luc Vanhoeck, Belgian Astronomical Association (VVS) Section Astrophotography, Elsbos 16, B-2520, Edegem, Belgium.

July 28
Stellafane, Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.

July 28
Ohio Turnpike Astronomers Association Convention, Hiram College, Hiram, Ohio. Sponsored by the Cuyahoga Astronomical Association. Contact: Gary Kader, 2580 Northglen Dr., Westlake, OH 44115.

August 1-4
ALCON '84, National Convention of the Astronomical League, Carroll College, Waukesha, Wisconsin. Hosted by Milwaukee Astronomical Society. Contact: ALCON '84, P.O. Box 275, Mequon, WI 53092.

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Astromart '84, an astronomy equipment fair held simultaneously with ALCON '84. Carroll College, Waukesha, Wisconsin. Hosted by ASTRONOMY Magazine. Contact: Dana-Lynne Terry, Advertising Coordinator, ASTRONOMY Magazine, P.O. Box 92788, Milwaukee, WI 53202. Phone (414) 276-2689.

August 6-10
Spitz Space Systems' Summer Institute in Planetarium Education, Chadds Ford, Pennsylvania. Contact: 1984 Planetarium Summer Institute, Spitz Space Systems, Inc., Rt. 1, Chadds Ford, PA 19317.

August 9-12
Convention of the Southeast Region of the Astronomical League, Pensacola, Florida. Co-hosted by Escambia Amateur Astronomer's Association and the University of West Florida. Contact: Merry E. Wooten, 6235 Omie Circle, Pensacola, FL 32504.

August 17-18
Near-IR and Solid-State Photometry Symposium, Lowell, Michigan. Hosted by IAPPP and Optec. Contact: Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

August 24-26
Connecticut River Valley Astronomers' Conjunction, Northfield Mountain Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Rd., Springfield, MA 01118.

August 24-26
Starfest '84, Third Annual Observing Convention of the North York Astronomical Association, The River Place, Mount Forest, Ontario, Canada. Contact: Andreas Gada, 145 St. George St., Toronto, Ontario, Canada M5R 2M1. Phone (416) 922-6294.

August 28-September 2
Eighth International Planetarium Directors Conference (professional meeting), Stuttgart, West Germany. Contact: Dr. Hans-Ulrich Keller, Director, Planetarium Stuttgart, Neckarstrasse 47, 7000 Stuttgart 1, West Germany

September 2-6
International Union of Amateur Astronomers General Assembly, Bologna, Italy. Contact: IUAA, C.P. 1630 AD, 40100 Bologna, Italy.

September 21-23
Astrofest. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P.O. Box 596, Tinley Park, IL 60477.

September 22
Ohio Turnpike Astronomers Association Convention, Akron, Ohio. Sponsored by the Astronomy Club of Akron. Contact: Philip Hegenderfer, 5070 Manchester Rd., Akron, OH 44319.

October 9-12
16th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society (professional meeting), Kailua Kona, Hawaii. Contact: David Morrison, Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822.

October 13-16
Conference on the Origin of the Moon (professional meeting), Kona, Hawaii. Sponsored by the Lunar and Planetary Institute and the Division for Planetary Sciences of the American Astronomical Society. Contact: Pam Jones, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058. Phone (713) 486-2150.

October 19-21
Sixth Annual Custer Astronomy Club Jamboree, Southold, Long Island, New York. Contact: Warren E. Hamburger, President, 320 Asharoken Blvd., Bay Shore, NY 11706. Phone (516) 666-8654.

October 24-27
Great Lakes Planetarium Association Conference, Milwaukee, Wisconsin. Contact: Gary E. Sampson, Wauwatosa West High School Planetarium, 11400 West Center St., Milwaukee, WI 53222.

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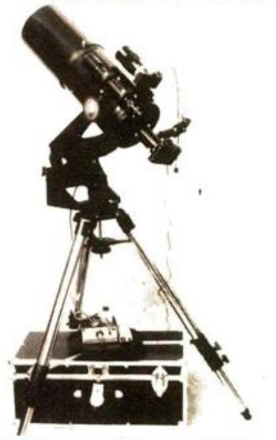

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A New Source of Cosmic Rays?

by Nebojsa Duric

The story of cosmic rays begins early this century — 1912, to be exact, the same year the *Titanic* sank on its maiden voyage, Zane Grey's Western romance *Riders of the Purple Sage* was topping the bestseller lists, and Henry Ford was stamping out 26,000 Model Ts a month. During the spring, summer, and fall of that year, an Austrian physicist named Victor Hess made a series of balloon flights during which his experimental instruments gave strong evidence that the mysterious "penetrating radiation" noted previously by many researchers became much stronger and more prevalent at high altitudes. But confirmation of Hess' results had to wait over a decade — until the American physicist Robert Millikan established beyond question that the source of the radiation lay outside the atmosphere. The particles were therefore dubbed "cosmic rays."

As their great penetrating power suggested, cosmic rays move at velocities close to that of light and are in fact the most energetic bits of matter in the universe. Yet over the years since their discovery, physicists and astronomers have learned remarkably little about them. Cosmic radiation is unquestionably particulate — mostly simple electrons and protons, although every element in the periodic table through lead has also been found among them. But in a way yet unknown, these particles have been broken away from their parent atoms and accelerated to velocities and energies billions of times higher than they would ordinarily possess. Cosmic rays are so energetic that they contribute fully half the energy found at any one time in interstellar space, even though their absolute numbers are relatively few. Above the atmosphere, a surface area of about five square centimeters would experience a little over four hits by cosmic rays every second. The rays come from all directions and fill space to an amazingly uniform degree — in free space, flux rates vary by less than one percent.

Cosmic rays are also detected at the Earth's surface, though in a form much modified by their passage through the atmosphere. As a ray impinges on the gases of the atmosphere, it breaks up atmospheric atoms and molecules and sends down a complex shower of secondary particles and by-products. These include pions, mesons, and muons, as well as electrons, positrons, and gamma rays. The by-products in such a cascade afford physicists glimpses of matter at energies higher than any that can be produced in manmade particle accelerators.

How can we study these rays? Besides investigating the results of a cosmic-ray shower in the atmosphere, astronomers can, under certain conditions, also detect cosmic rays in space by their effects on other matter.

Cosmic ray electrons, for example, interact with the Galaxy's magnetic field to produce what is known as synchrotron radiation. This is the name given to the photons that a charged particle (such as an electron) radiates when it spirals around in a magnetic field. It was first observed in synchrotron particle accelerators in the 1940s and occurs because any charged particle undergoing acceleration (such as following a spiral path) must emit radiation. Since the electron is a lightweight particle and only weak accelerations are needed to deflect it, the photons it produces tend to have low energies and are most readily detected in the radio portion of the electromagnetic spectrum. By applying what we have learned of the geometry of the galactic magnetic field from other methods of study, we can use synchrotron radiation to trace the distribution of cosmic-ray electrons that belong to the Milky Way Galaxy.

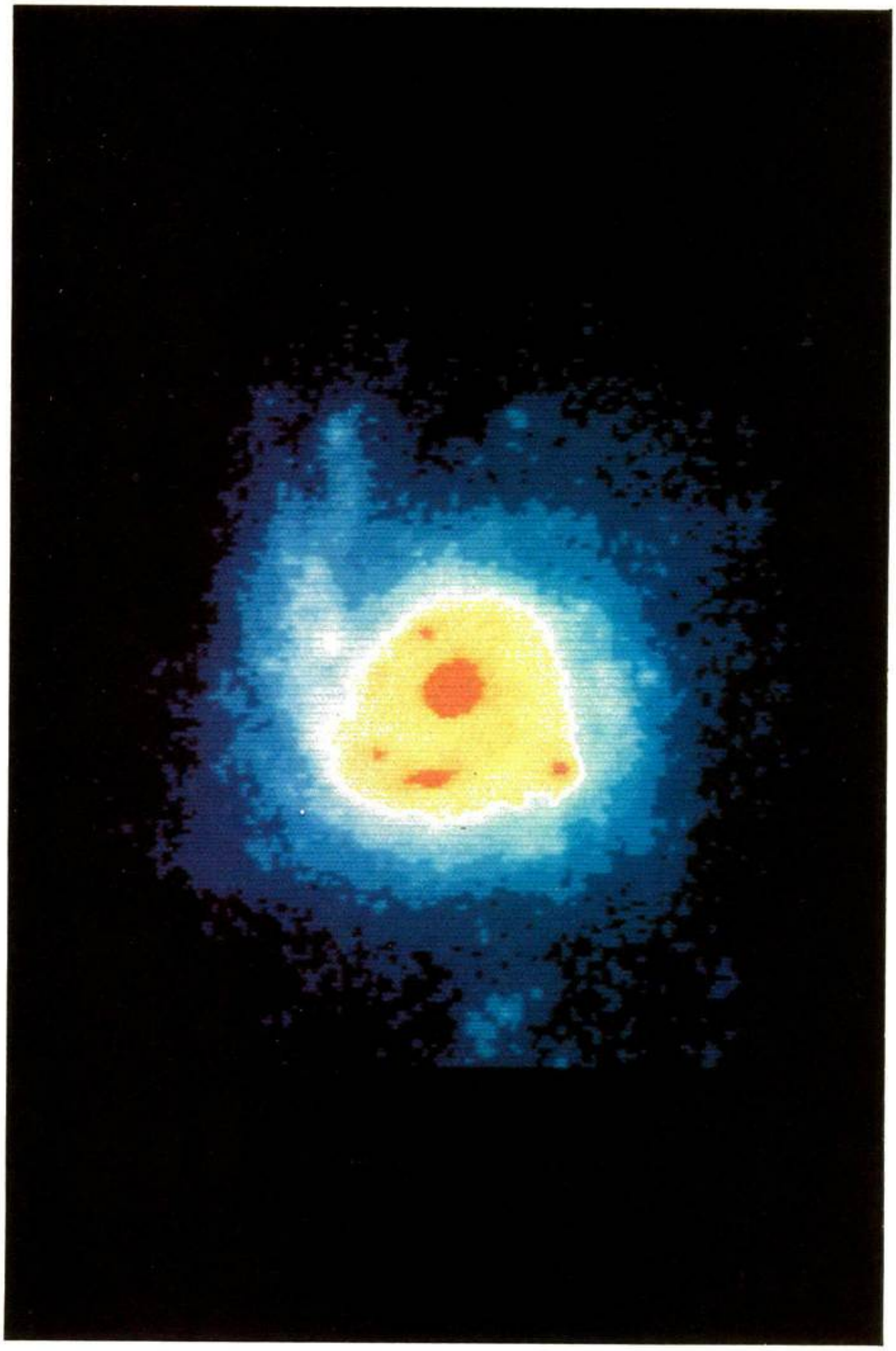
But cosmic rays aren't just made up of electrons, and to study the other type calls for a different technique. The cosmic rays made up of nuclei are heavier and tend to move somewhat more slowly. (The simplest nucleus — a proton — has over 1800 times the mass of an electron.) More resistant to accelerating forces, they are poor emitters of synchrotron radiation. Instead, cosmic-ray nuclei become evident mainly when they interact with the interstellar gas. In ways similar to what happens when cosmic rays crash into the Earth's atmosphere, violent collisions between cosmic-ray nuclei and particles in the interstellar gas result in the production of gamma rays — the most energetic photons in the electromagnetic spectrum. Detecting these photons by orbiting gamma-ray telescopes has led astronomers to a better understanding of how cosmic-ray nuclei are distributed in our Galaxy.

By combining these studies — of both the highest and lowest energy photons — cosmic-ray astronomers have established that only some of the cosmic rays permeating the Galaxy can come from discrete energetic sources such as supernova remnants. The rest of the radiation is diffuse and its origin not at all obvious. One recent paper shows that at least some of the cosmic-ray nuclei probably come from outside our Galaxy. So the 70-year-old question still calls for an answer — where do cosmic rays come from? What kind or kinds of events can impart such energies?

Oddly enough, to get to grips with this puzzle we do better to look at galaxies other than our own. The problem is largely one of not being able to see the forest for the trees. As we peer into the thickly populated disk of our Galaxy, we find dense clouds of dust obscuring our vision and greatly complicating the job of identifying optical counterparts of cosmic-ray sources. By looking at other galaxies, we neatly avoid this problem but encounter another — because of the greater distances involved, the radiation we receive is much weaker.

At present, gamma-ray telescopes are more hindered than are radio telescopes because the available instruments lack sufficient sensitivity and resolution. This severely limits what can be learned about cosmic-ray nuclei. However, the study of cosmic-ray *electrons* is less restricted. Today's radio telescopes

NGC-3310, seen here in a computer-processed infrared image, is a 10th magnitude spiral galaxy in Ursa Major. Despite its rather ragged appearance, the nucleus and several "hot spots" show clearly and there is some slight evidence for spiral arms. Compare this photo with those on the next page and following. All photos courtesy of the author.

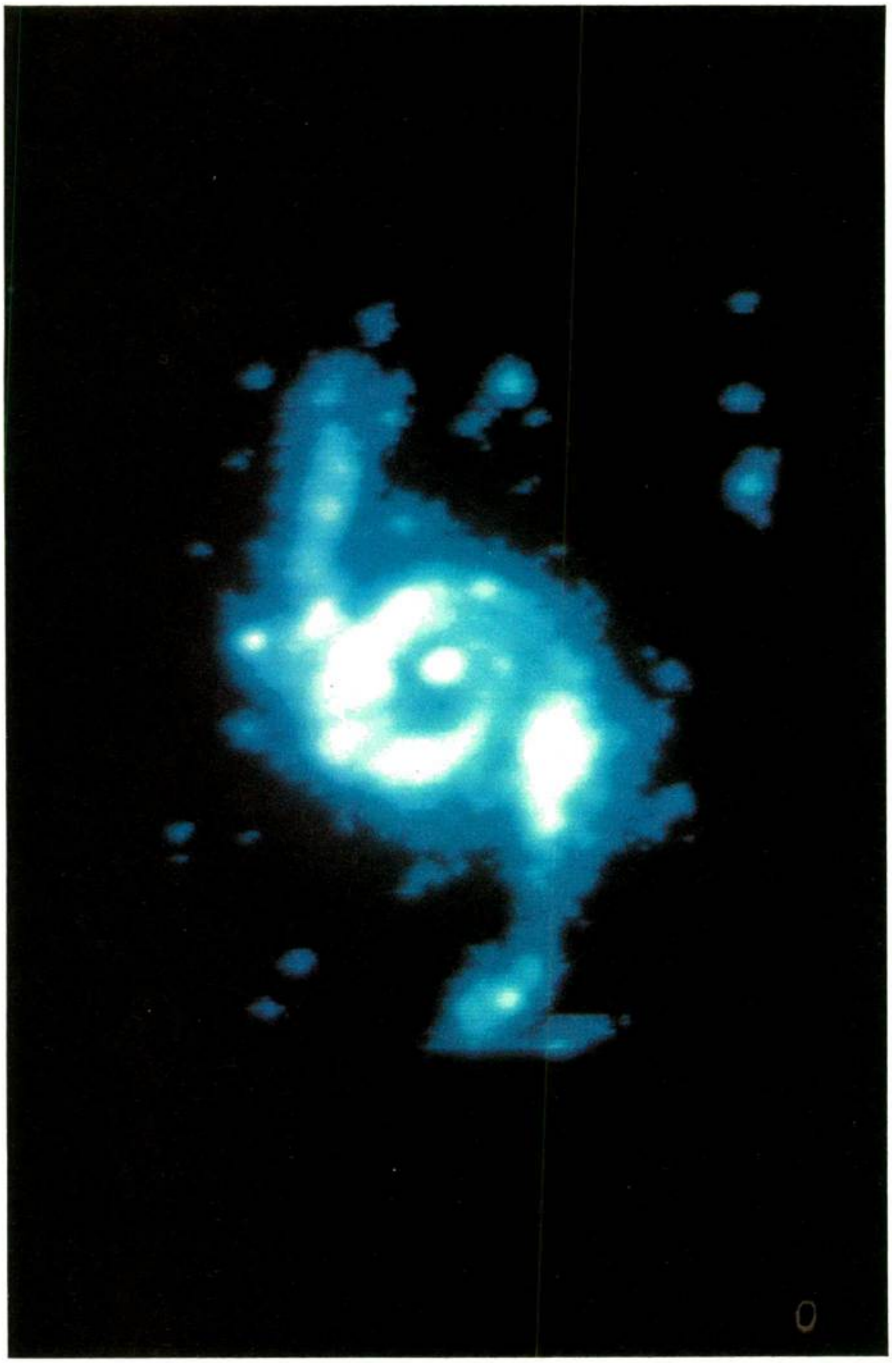


have enough sensitivity to detect and map the synchrotron emission in other galaxies. To put their radio maps to use, astronomers have tried to compare how sources of synchrotron radiation correlate with the different colors of optical radiation. Tying together the images made at different wavelengths allows them to study possible relationships between cosmic-ray electrons, stars, and ionized gas.

Multicolor images of a galaxy reveal how different types of stars are distributed according to color, temperature, and age. For example, stars that are prominent at blue wavelengths tend to be hotter and more massive. This in turn means that these high-luminosity stars will tend to have shorter lifetimes and must therefore belong to a recent generation (or population) of stars. Such young stars make up what astronomers call Population I and are generally found lining the spiral arms of galaxies. (Though not as hot or as young as a typical blue star, the Sun belongs to our Galaxy's Population I.) Stars whose dominant light is reddish tend to be cooler, less massive, and longer-lived; they are distributed throughout the disk of a spiral galaxy and belong to Population II. Finally, by isolating a particular wavelength — that of hydrogen-alpha (Hα) at 6563 Angstroms — and taking a galaxy's picture in that single color, astronomers can also trace the patches of ionized hydrogen often found near regions of recent star-formation.

Early attempts at using the comparative radio/optical approach produced conflicting results. In some cases, it appeared that the distribution of synchrotron radiation followed that of red starlight — implying a connection between cosmic-ray electrons and Population II stars. If that really were the case, the stars most likely to be producing the cosmic-ray electrons would be M- and K-type flare stars. These are lower main-sequence stars with surface temperatures of about 3500° K to 5000° K, which have unusually large flares — the energetic flares being the source of the cosmic-ray electrons. Since these stars are distributed uniformly across disks of spiral galaxies, the cosmic-ray electrons would also be distributed this way.

On the other hand, different studies have shown that synchrotron radiation follows blue starlight, which is dominated by the hot blue Population I stars. This suggests that cosmic-ray electrons come from objects such as supernovae, supernova



In the light of ionized hydrogen (Hα), the nucleus of NGC-3310 dwindles in significance, but the spiral arms become much more prominent. In essence, this image shows where stars are being formed in the galaxy at present.

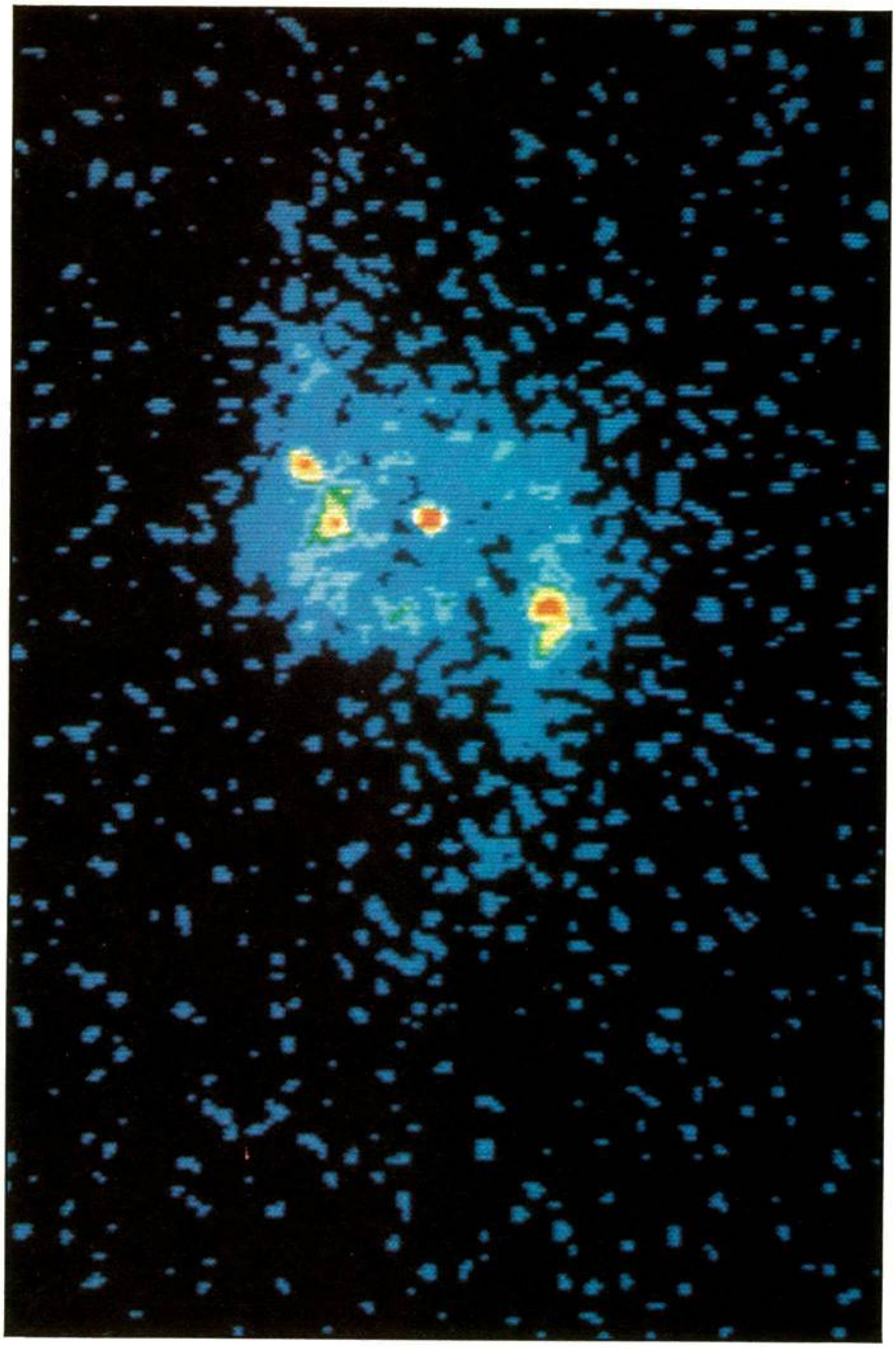
remnants, and pulsars — all of which are energetic and could produce the rays. In this case, the cosmic-ray electrons would be distributed primarily along the spiral arms of galaxies.

This contradiction may be more apparent than real, since two factors are at work. First, it is possible that *both* populations of stars may be producing cosmic rays at the same time, but in varying proportions. Second, the low resolution of the early radio observations (at least 10 times coarser than optical), and the limited fields of view of radio interferometers, make it difficult to study the correlations in even the nearest galaxies. What these studies needed was a radio instrument that could provide resolution as good as that in the optical. The only radio interferometer capable of such resolution is the Very Large Array (VLA) in Socorro, New Mexico, which is operated by the National Radio Astronomy Observatory. Even this instrument, however, has a limited field of view. To use it effectively, it is necessary to pick galaxies with angular sizes small enough to fit in the field of view. This has the drawback of forcing one to work with faint and distant galaxies, but it does offer a way of settling the contradiction.

Eager to try this approach, I embarked on a project with Ernie Seaquist of the University of Toronto, Lindsey Davis of Kitt Peak National Observatory, and Patrick Crane and Carl Bignell of the VLA to observe a galaxy at resolutions of one to two seconds of arc using both optical and radio means. The galaxy we chose was NGC-3310, a 10th magnitude spiral galaxy in Ursa Major near the Dipper's bowl. (On a good night, it is easily visible in medium-size backyard telescopes.) We picked NGC-3310 because of its high radio and optical brightness, its clearly defined spiral arms, and because it is small enough (about two arcminutes in diameter) to fit in the field of view of the VLA.

When we compared the optical and radio data, we saw that, of the optical images, Hα has the most similarity to the radio map. Since the 20-centimeter radio image is dominated by synchrotron radiation and since the Hα is a "tracer" of ionized gas, the cosmic-ray electrons appear most closely related to either the ionized gas itself or to the very recently formed stars embedded within it. Therefore, if the cosmic-ray electrons are being produced in these regions, they are either produced in the star-forming regions by supernova-related objects

At a radio wavelength of 6 cm, the spiral structure dominates. Looking more closely, we see a fairly smooth layer of weak synchrotron emission, shown in blue, punctuated by patchy bits of stronger emission in white, yellow, and red. The patchy areas correlate with the regions of ionized hydrogen and show cosmic-ray electrons coming from places where stars are forming, along with some radiation from ionized hydrogen.

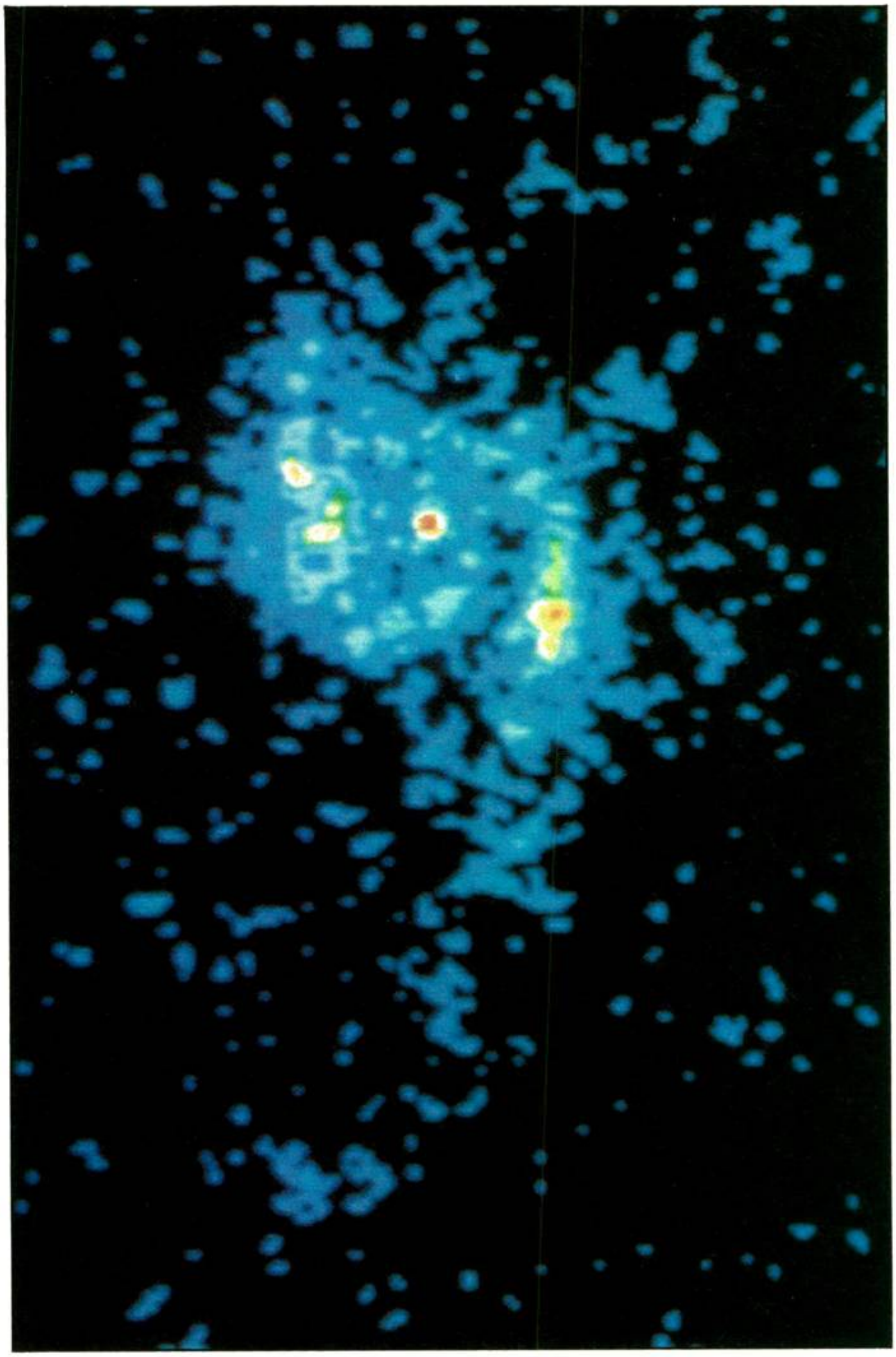


(supernovae or their remnants) — or by the very mechanism that is causing stars to form.

The 6 and 20 cm wavelength "photos" show that the radio emission consists of two components. One component is clumpy and is associated with regions of ionized hydrogen. As these clumps are partly made up of synchrotron radiation, the sources of some cosmic-ray electrons must lie within the star-forming regions. The other component is underlying, smooth, and more coherent; it delineates the spiral arms at 20 centimeters. The strongly defined geometry and smoothness of this radiation precludes the possibility that it has leaked from more patchily distributed star-forming regions. Where then does this smooth component come from?

As we've seen, the cosmic-ray electrons associated with star-forming regions are probably supernova-related; this can easily account for the amount of synchrotron radiation actually observed. So far, so good. However, the large-scale distribution of cosmic-ray electrons is a little more difficult to explain. The fact that the radiation follows the shape of the spiral arms suggests it may be associated with whatever it is that gives them that shape. Many astronomers now think that spiral arms come from density waves (see "To Sculpt the Galaxies," ASTRONOMY, January 1983). It is possible that the spiral density waves themselves may be causing the synchrotron emission. A density wave is a wave passing through the disk of a spiral galaxy in which the density of material (stars, gas, dust) is compressed or enhanced. The crest of such a wave can move faster than the speed of sound in the gas, therefore a shock front results.

The boom you hear when a jet goes supersonic is very similar to what happens when the crest of a density wave passes. In our atmosphere, the air is compressed; in the galaxy, the gas is compressed, energized, and accelerated. Some have argued that the shock front of a density wave may simply compress any cosmic rays already present in the disk of the galaxy, but not accelerate them. This would enhance the synchrotron emission in the arms without necessarily producing new cosmic rays. Although this mechanism may work for some galaxies, it does not work for NGC-3310 because the enhancement there is much greater than what theory predicts for a simple compression. Therefore, we ought to consider it possible that cosmic rays (or



At a longer wavelength of 20 cm, the picture is much the same as it is at 6 cm, but in this case, the emission is overwhelmingly due to cosmic-ray electrons. Astronomers have had little difficulty accounting for the patchy cosmic-ray emission — it follows from standard models known for years. But by its very extent, the widespread smooth emission posed problems. Astronomers are now considering an additional source of synchrotron emission: the density waves that create and maintain the spiral structure of galaxies.

at least the electron variety) are actually produced in the shock front of the density wave.

How? Cosmic ray electrons could result as the turbulent gas in and around the shock front violently bounced, tumbled, and shoved less-energetic electrons. If this were true — and a lot more theoretical work must be done to eliminate other possibilities — we are seeing density waves themselves produce cosmic rays. This new twist is exciting because for the first time astronomers can look beyond the simplistic Population I *vs.* Population II debate. The evidence is clear that in the case of NGC-3310 at least, the bulk of the cosmic-ray electrons comes from *neither* population of stars.

Unfortunately, it's still too early to hope for a similar degree of progress regarding the origin of cosmic-ray nuclei. The hitch here is the extremely limited sensitivity of present-day gamma-ray telescopes. Although it is tempting to guess that cosmic-ray nuclei also come from the same places as the electrons, there is no evidence to suggest it. However, some cosmic-ray nuclei must come from density waves — if only because it is difficult to imagine reasonable mechanisms that can accelerate only electrons.

What can we conclude from all this? It is now clear that for at least one galaxy, we can account for cosmic-ray electrons with processes that work on local scales in star-forming regions (such as supernova remnants), and on more global scales by density waves. We can't yet say if this applies to other galaxies, since none have yet been studied this way. (In fact, when we do, we may find that still other mechanisms are also responsible.) But the results on NGC-3310 show that the overall picture — whatever its final details come out to be — is both richer and more complex than we had thought. And paradoxically, increasing the complexity actually eases the work of astronomers, since it opens up many more exciting possibilities.

Nebojsa Duric is currently in the final year of his Ph.D. program in astronomy and astrophysics at the University of Toronto. Most of his work has been in the study of radio continuum emission from spiral galaxies with particular emphasis on the origin of cosmic-ray electrons.

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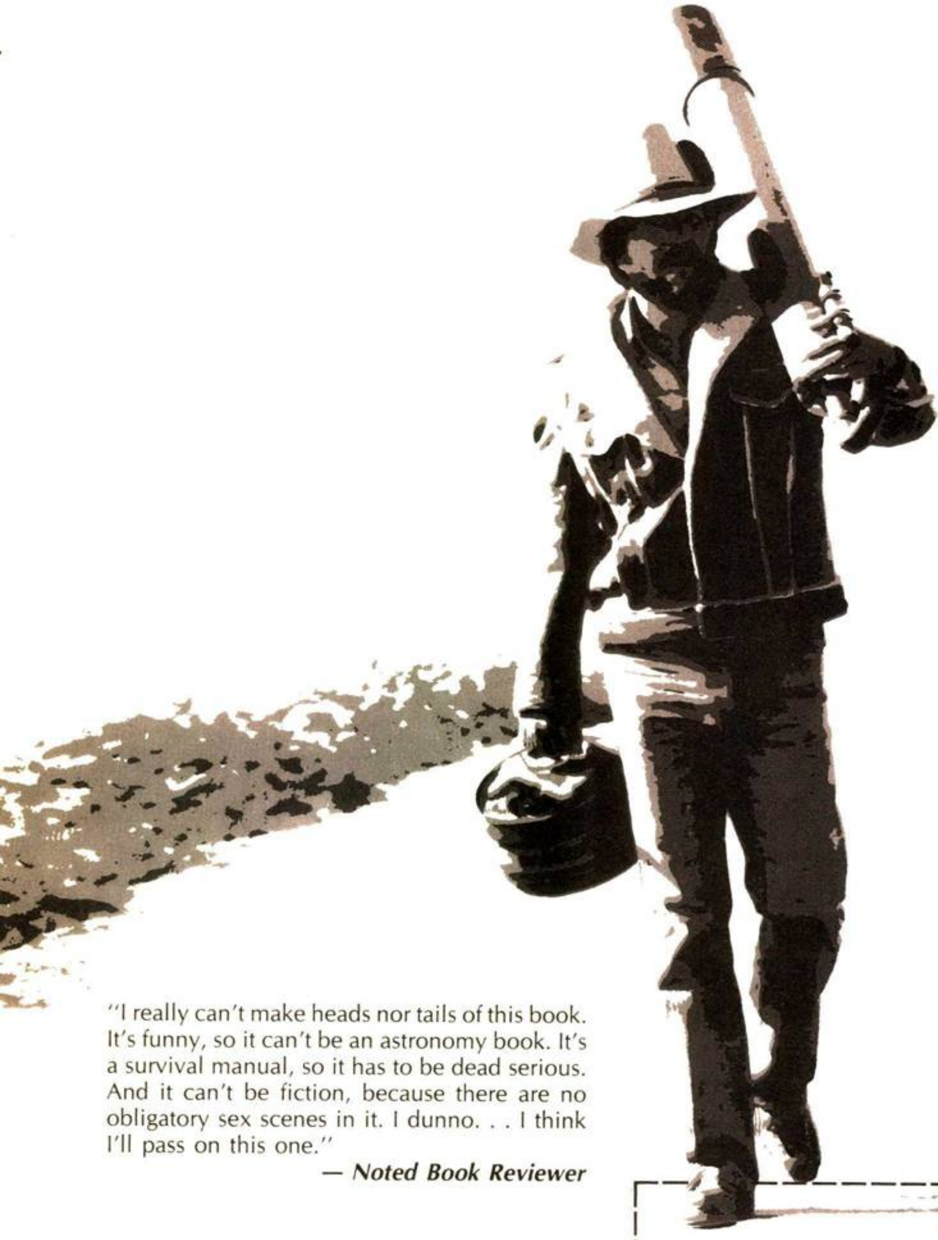

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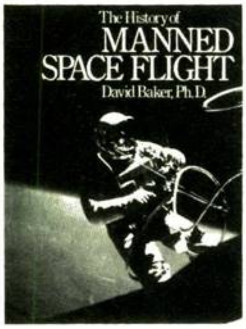
by David Baker



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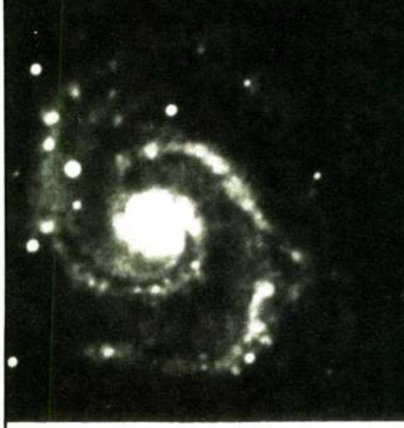

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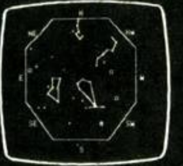

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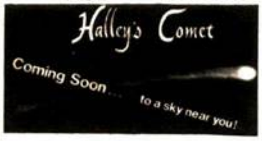
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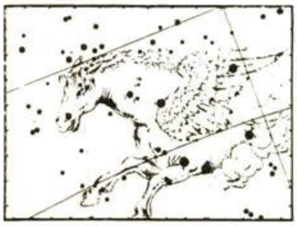

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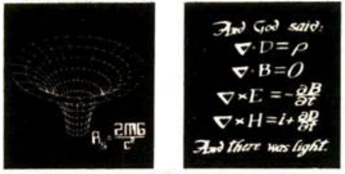
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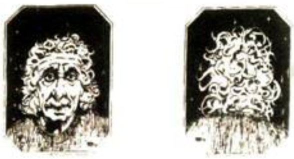
And there was light.

5

Front: Black hole w/ Schwartzchild's radius.
Back: Maxwell's equations of light.



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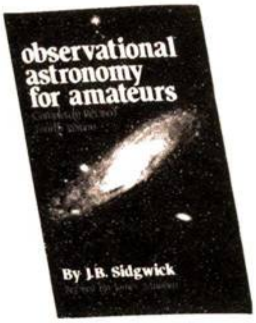

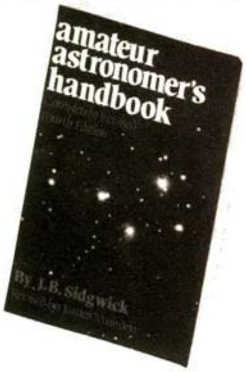

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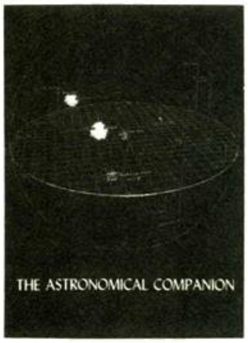

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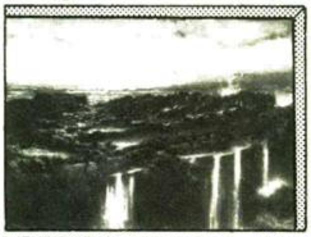

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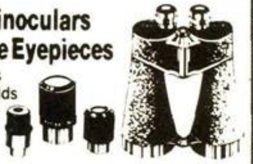

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Make Your Dobsonian Telescope Easier to Use

**by
Bryan Shumaker**

One of the chief delights of a Dobsonian-mounted telescope is its portability. These simple and inexpensive mountings have brought big telescope performance into the reach of ordinary amateur observers, and being able to transport large instruments to dark skies has increased the popularity of the Dobsonian telescope almost explosively.

But even though my homebuilt 8-inch f/6 Dobsonian is relatively easy to move and set up, I found that I was lugging along just as many accessories as I did with my trusty old equatorial. You know: clipboards, log-books, red flashlight, eyepieces, cases, filters, adapters — all that stuff. I'd even reached the point of taking a *table* with me to keep it handy! But after one particularly exasperating night when my Messier finder cards scattered to the winds across an open field, I knew I had to find a better way.

Financial considerations ruled out hiring a butler, so I started looking into what I could buy or make on a shoestring budget. I had noticed that any Dobsonian has a wonderful place to put often-used items — the sideboards of the rocker box. Was there any way to put that to use?

Well, a little browsing in my local K-Mart turned up a $2 plastic toolcase with compartmented open-out drawers. I removed one of the drawers completely and cut away some of the compartment dividers in the remaining drawer. I fitted a piece of ¼" plywood into the box below and in front of the drawer, then drilled five holes in it with a 1¼" hole saw to hold my eyepieces. (I have only four right now, but why not plan ahead?) The compartments in the drawer above hold my Barlow, nebular filter, some adapter rings, an adjustable wrench, lens paper, and a pencil. Actually, I've got more room than I need, but I figure it'll fill up soon enough.

Next, I cut two slotted holes in the top of the case; these fit over two large-headed screws on the rocker, which I screwed in until ¼" was left sticking out. When I set up to observe, I simply open the case and hang it on the screwheads. Between the slots in the case-top I attached a small spring clip — this securely holds my finder cards or a list of viewing objects. Finally, since I sometimes use a clipboard, I found that putting another small, barely protruding screw into the side of the rocker provided a place to hang it.

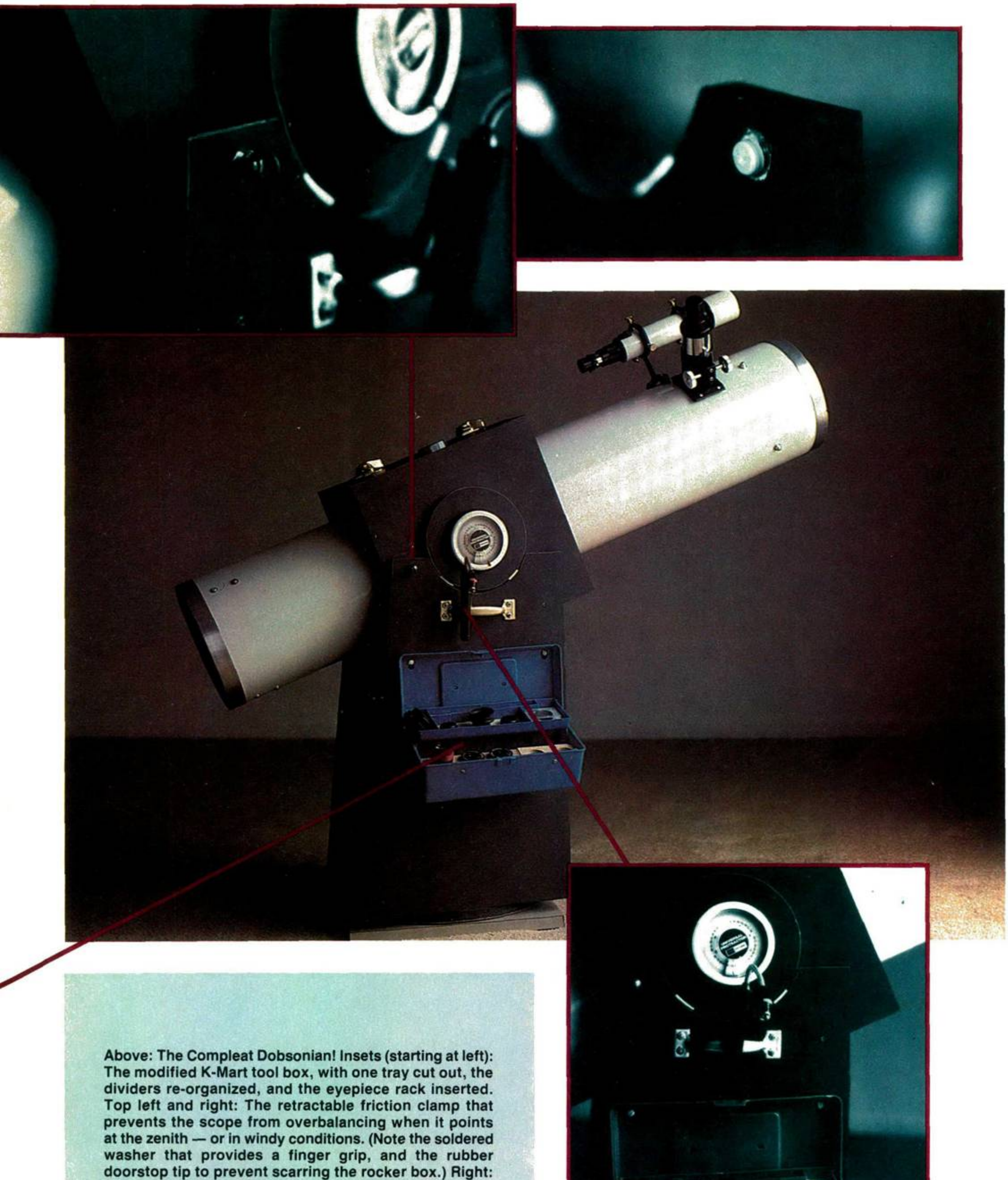
Now, it's obvious that all this neatly stored equipment isn't going to be very useful if you have to fumble around in the dark to find what you need. My cheap solution was a small gooseneck penlight, which I found locally for $3. (A coat or two of red nail polish on the bulb works great to dim the light.) I attach it to the sideboard with one of those broom-handle clips you can get in hardware stores. Other penlight models come with a spring clip and can be hung just about anywhere there is an edge to grab.

With the accessories under control, there was one more modification I had to make. When I point my scope at the zenith, I find the weight of the focuser and the finder tend to pull it backward. The side bearings haven't enough friction to hold the scope on target.

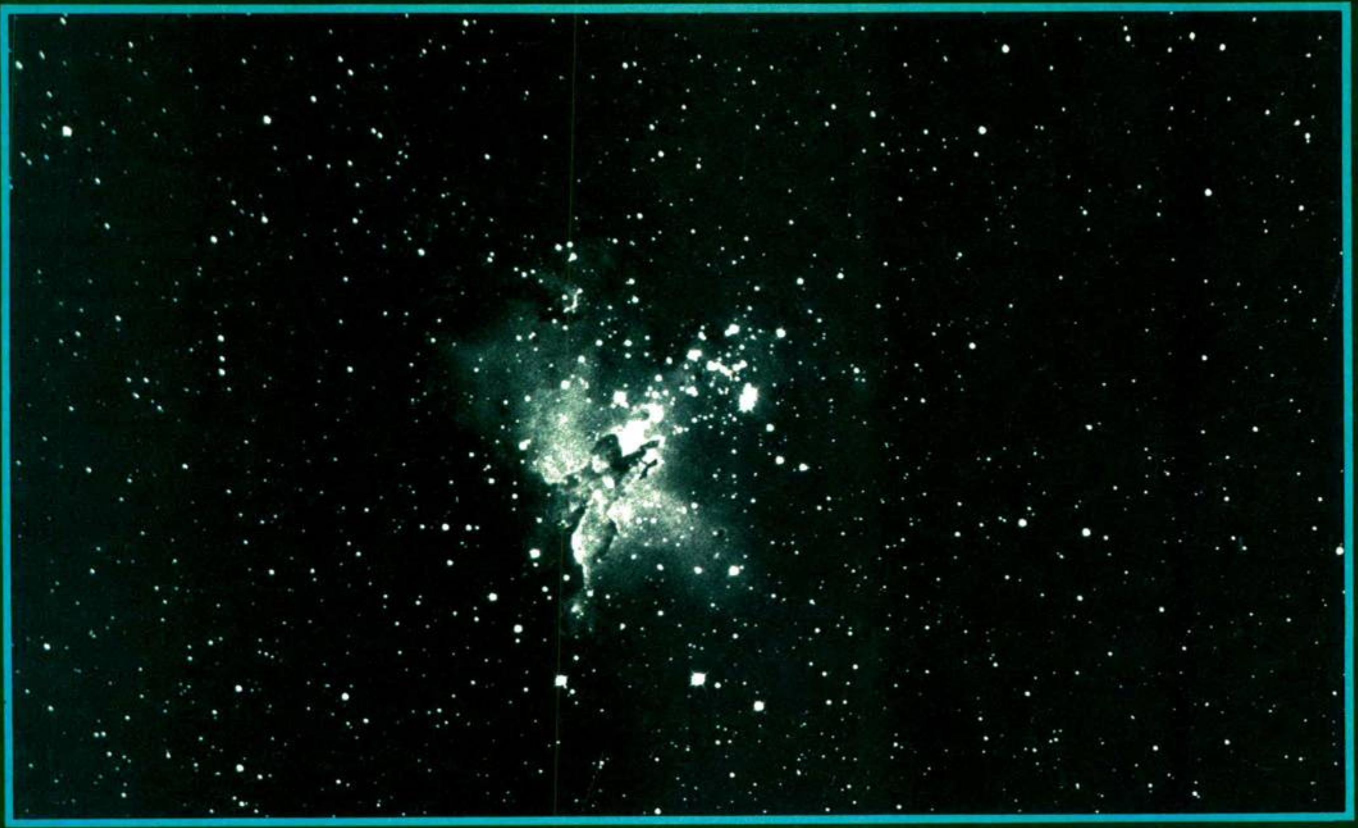
My adjustable friction screw is very simple: a bolt passes through the rocker and butts against the box. I embedded a nut (you could use a tee-nut as well) in the sideboard and an old rubber doorstop cap fits over the tip of the bolt to prevent scarring. If necessary, enlarge the hole on the inside of the rocker to accommodate the cap when fully retracted. I then soldered a washer to the bolt head for an easier grip — but you can get bolts with a wingnut already attached. In use, you gradually tighten the bolt until the pressure on the box gives you the friction you need. I find I have to engage it only when the scope is pointed right at the zenith or when conditions are very windy.

Although I still use my old equatorial mount relatively frequently, my newly modified homebuilt Dobsonian "with all the amenities" has made my remote dark-sky observing simple, organized, and an absolute delight!

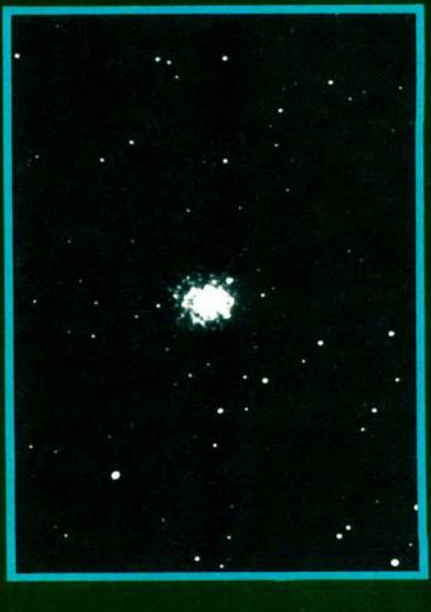
Bryan Shumaker lives near Detroit and has been interested in astronomy since the age of 13, when he helped an uncle grind a 3-inch mirror. He is now at work on a 12.5-inch for deep-sky observing.



Above: The Compleat Dobsonian! Insets (starting at left): The modified K-Mart tool box, with one tray cut out, the dividers re-organized, and the eyepiece rack inserted. Top left and right: The retractable friction clamp that prevents the scope from overbalancing when it points at the zenith — or in windy conditions. (Note the soldered washer that provides a finger grip, and the rubber doorstop tip to prevent scarring the rocker box.) Right: The gooseneck penlight means no more groping in the dark for eyepieces or tools. Since it unclips, you can hold it over your log book to make notes. (That's a protractor you see above the light, mounted on the side bearing to give elevations.) All photos from the author.



Above: The Eagle Nebula (M-16) in Serpens Cauda is a rich complex of dust, glowing hydrogen gas, and newly formed stars. Though only a large telescope will show much of the gas, the cluster of new stars is far more prominent. Photo by Alfred Lilge. Left: This scanty sprinkling of stars is IC 4665, a loose open cluster in Ophiuchus — use low magnifications when scanning for this one! Photo by Jamey Jenkins. Bottom left: Although a globular cluster, M-12 has a loose appearance that makes its individual stars easy to resolve. Photo by Jay Anderson. Bottom center: NGC-6369 is a dim planetary nebula — a faint cousin of Lyra's famed Ring Nebula. Photo by Martin Germano. Bottom right: M-62 is a tighter and richer globular than M-12; look for a condensed core with a soft periphery. Photo by T.L. Dessert.

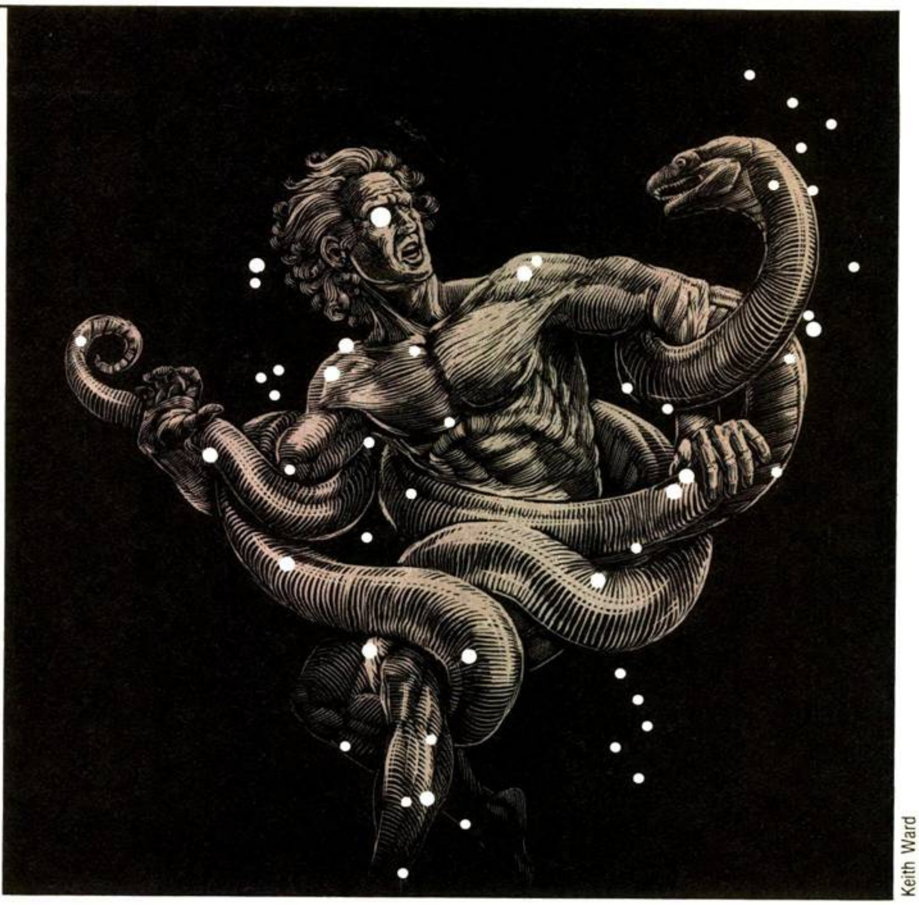


Ophiuchus

Oph
Ophiuchi

Serpens Cauda

Ser
Serpentis



Keith Ward

Lying adjacent to the main line of the summer Milky Way, the large, box-shaped constellation **Ophiuchus**, the Serpent-Bearer, holds many globular star clusters, open clusters, planetary nebulae, and unusual stars — and even contains one galaxy! Sandwiched between Ophiuchus and the bright star clouds toward the galactic center is **Serpens Cauda**, the tail of the Serpent, home to a variety of objects.

The brightest globular in Ophiuchus is **M-62** (NGC-6266), a magnitude 6.5 cluster lying about 7° southeast of Antares nearly on the border with Scorpius. It measures 14.1′ across, but backyard telescopes show it to be considerably smaller. (Globular cluster diameters are based on long photographic exposures, which reveal many tiny stars far removed from the cluster's center.) M-62 is a moderately compressed and asymmetrical globular — its major axis points toward position angle 75° — and the average magnitude of its brightest 25 stars is 15.9. M-62 lies 6 kiloparsecs (kpc) from the Sun and measures 25 parsecs (pc) across; it contains a remarkable 89 known variable stars, most of which are RR Lyrae-type stars.

About 4.5° north of M-62 is the similarly bright globular **M-19** (NGC-6273), a cluster shining at magnitude 6.8 and measuring 13.5′ across. M-19 is a "looser" globular than M-62 — it is easier to resolve into individual stars. A 6-inch scope on good nights will resolve M-19's outer edges, whereas an 8-incher is needed for even a hint of resolution with M-62. On good nights, assuming your telescope is properly collimated, you can use magnifications of 20x to 30x per inch of telescopic aperture. M-19 lies at a distance of 10.1 kpc and is a large globular, measuring 40 pc across. Visible in the eyepiece and in amateur photos of M-19 is its highly oblate shape: its long axis is oriented almost due north-south, at p.a. 15°.

An unusual pair of objects lies northeast of M-19, near the bright stars Theta (θ) and Omicron (ο) Ophiuchi. **NGC-6369**, a ring-shaped planetary nebula, is a fine sight in small telescopes. It glows at magnitude 11, measures 28″ across, and has a fairly high surface brightness (it can stand lots of magnification). Its 16th magnitude central star will challenge the largest backyard telescopes, but medium-sized instruments show a perfectly formed ring. A mere 1.5° north-northeast of θ Oph is the elusive dark nebula **Barnard 72**, known as the "S" Nebula. Its obscuring dust, backlit by stars and nebulosity, spans 30′ in the shape of the letter S. On a dark night, with a wide-field eyepiece, even small telescopes faintly show this patch of dust grains. But if the Moon is out or the transparency poor, you won't find B72.

The area contains two large, scattered open clusters: one lies in Ophiuchus, the other in Serpens Cauda. **IC 4756**, in Serpens, covers an area of more than 70′ and contains 80 stars of seventh magnitude and fainter. It is an impressive sight in binoculars, but loses appeal when subjected to the cramped fields of telescopes. **IC 4665**, just northeast of Beta (β) Oph, is somewhat smaller and much sparser yet: it contains 20 stars of magnitude 7 and fainter in its 55′ diameter. Again, binoculars and finder scopes provide the best views.

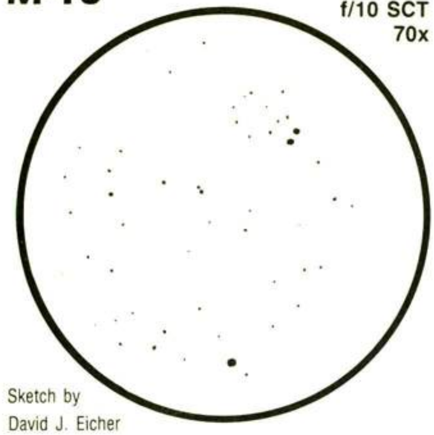
Straddling IC 4665 on opposite sides are the out-of-place galaxy **NGC-6384**, an Sb-type spiral, and **Barnard's Star**, a star with one of the highest known proper motions. The galaxy measures 4.0′ x 3.0′ and glows softly at magnitude 12.3, making it visible as a smudge in a 6-inch scope and as an elongated blur with a bright middle in an 8-inch instrument. Barnard's Star, a faint red dwarf only 6 light-years away (this is the second closest star system to the Sun), shines at magnitude 9.5 and is recognizable by its ruddy hue. Its great proper motion — more than 10″ per year — results in part from its close proximity; over 351 years, Barnard's Star traverses an entire degree of sky! Sproul Observatory astronomer Peter van de Kamp has reported a "wobble" in the star's motion and maintains that it is due to a large planetary companion. This has yet to be proven.

Ophiuchus contains many more globular clusters, including two of the finest anywhere in the sky — **M-10** (NGC-6254) and **M-12** (NGC-6218). The two are nearly identical and lie only a few degrees apart. M-10 shines at magnitude 6.6 and measures 15.1′ across; M-12 radiates at magnitude 6.9 and is 14.5′ in

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

M-16

8-inch
f/10 SCT
70x



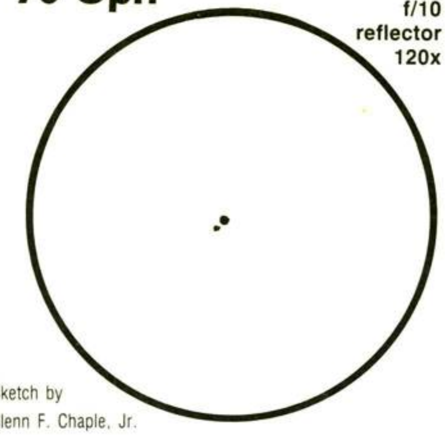
Sketch by
David J. Eicher

diameter. Both clusters make superb targets for all telescopes, and 6-inch telescopes at high power resolve their peripheries beautifully into gleaming pinpoints. (M-12 is slightly looser, but they are very nearly equal in resolvability.) On good nights, large amateur telescopes show stars across the entire faces of these clusters. M-10 lies 4.4 kpc away and measures 19 pc in physical diameter; M-12 is 5.9 kpc distant and fills a sphere measuring 25 pc.

Due east of the M-10/M-12 area is another bright globular, **M-14** (NGC-6402). This group of stars is a fainter, dimmer version of M-10 and M-12, but still is quite impressive in any telescope. At magnitude 7.5 and 11.7′ diameter, the group is a fuzzy spot in binoculars and shows up well in a 4-inch reflector. A 16-inch telescope at high power resolves M-14 across its face, leaving a misty grainy light suspended behind a curtain of glistening 15th magnitude stars. Although M-14 lies at the remote distance of 13.8 kpc, its large physical size of 47 pc causes it to appear as "one of the gang" among Ophiuchus globulars. It contains a high number of variable stars — 85, at last count.

70 Oph

3-inch
f/10
reflector
120x



Sketch by
Glenn F. Chaple, Jr.

Two more globulars, in the southern reaches of Ophiuchus, are easily visible in small telescopes. One is **M-9** (NGC-6333), a compact cluster that lies atop a prominent Milky Way dust cloud called Barnard 64. The cluster glows at magnitude 7.8, measures 9.3′ across, and can be partially resolved with amateur telescopes. It is 9.1 kpc away and measures 25 pc across. On dark nights, with a low-power eyepiece, the dark nebula appears as a black stain spilt onto the starry backdrop. The last globular is **M-107** (NGC-6171), an eighth-magnitude group spanning 10′ and lying at a distance of 6.7 kpc. It is a globular of average size, measuring 19 pc in extent.

Ophiuchus contains several double and variable stars; one is the famous double **70 Ophiuchi**. Discovered to be binary by William Herschel in 1779, 70 Ophiuchi's components are of magnitude 4.2 and 5.9, are separated by 1.8″ in p.a. 300° (1984), are yellowish and rose-colored, respectively, and are rapidly changing in separation and p.a. (The period is just over 88 years.) **X Ophiuchi** is a typical long-period variable whose magnitude range is 6.0 to 9.3 and whose period is 334 days — just short of one year. **RS Ophiuchi**, on the other hand, is one of seven so-called recurrent novae: in 1898, 1933, 1958, and 1967 this star underwent maxima in which it shone at fourth magnitude, becoming visible to the naked eye. Normally RS Oph glows dimly at magnitude 11.5. Systems like this one involve two stars, one of which may be a white dwarf. As hydrogen from the companion flows on to the white dwarf, the material heats up and explodes.

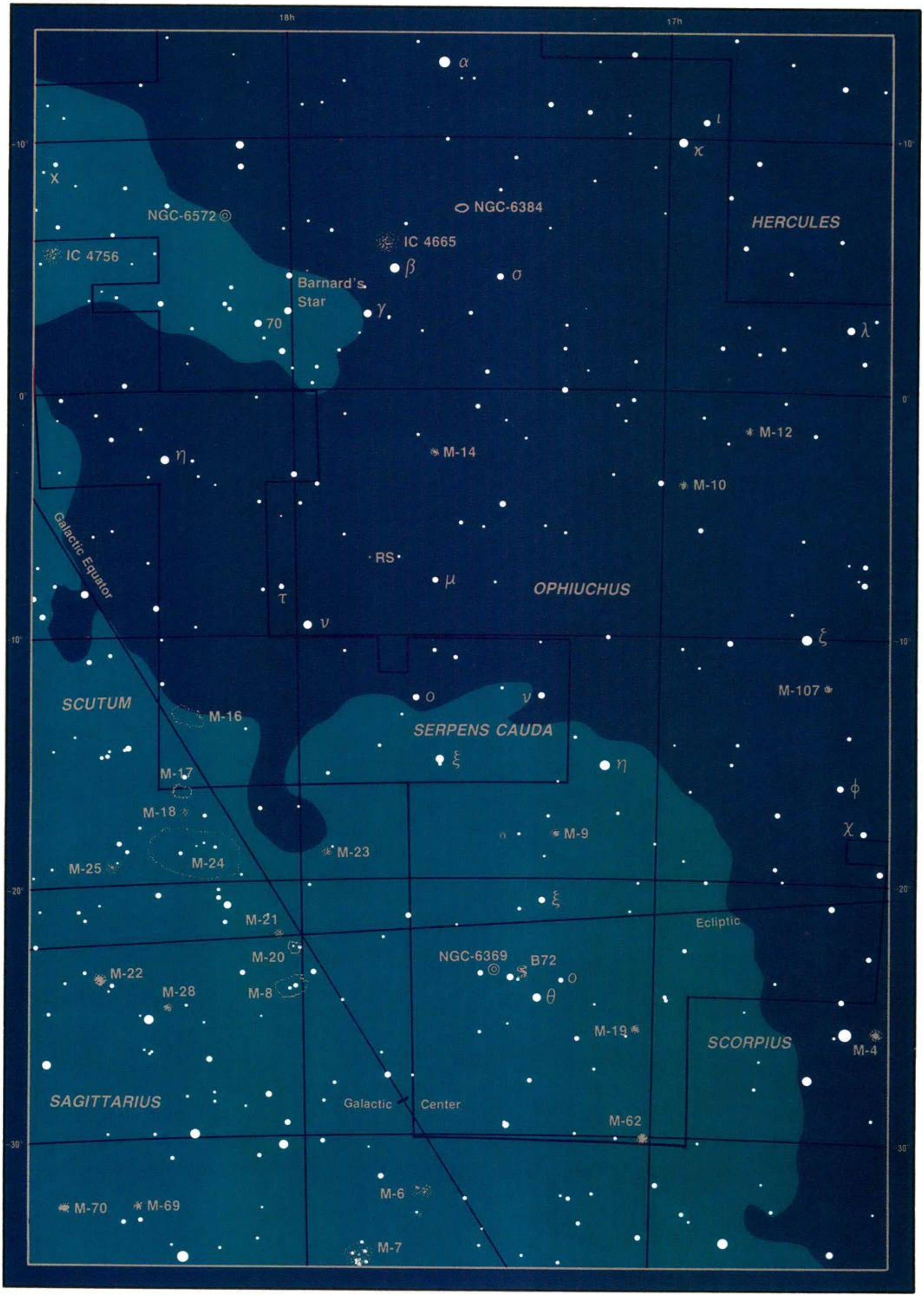
A fine planetary nebula in Ophiuchus is **NGC-6572**, a tiny, bright disk characterized by a strong blue-green hue. The nebula measures only 15″ x 12″ across and shines at 9th magnitude; a medium-sized scope on a dark night shows it easily and has a chance of revealing the nebula's central star, an O-type object of 12th magnitude.

Serpens Cauda contains one of the most unusual and complex regions of ionized hydrogen in our galactic neighborhood — **M-16** (NGC-6611), otherwise known as the Eagle Nebula. This large emission nebula is centered on a bright star cluster containing 60 stars of eighth magnitude and fainter in an area 25′ across. The star cluster makes for a fine binocular sight and, at sixth magnitude, is theoretically visible with the naked eye from a dark site. The challenging part of M-16 is spotting the glow from the gas that produced the cluster and now fluoresces under strong gusts from hot stellar winds. The nebulosity has a low surface brightness (and its visibility is further hindered by many bright stars in the field); in an 8-inch RFT at low power, it appears as a milky, greenish light. Larger scopes show more nebulosity and the dark globules that may be collapsing into protostars.

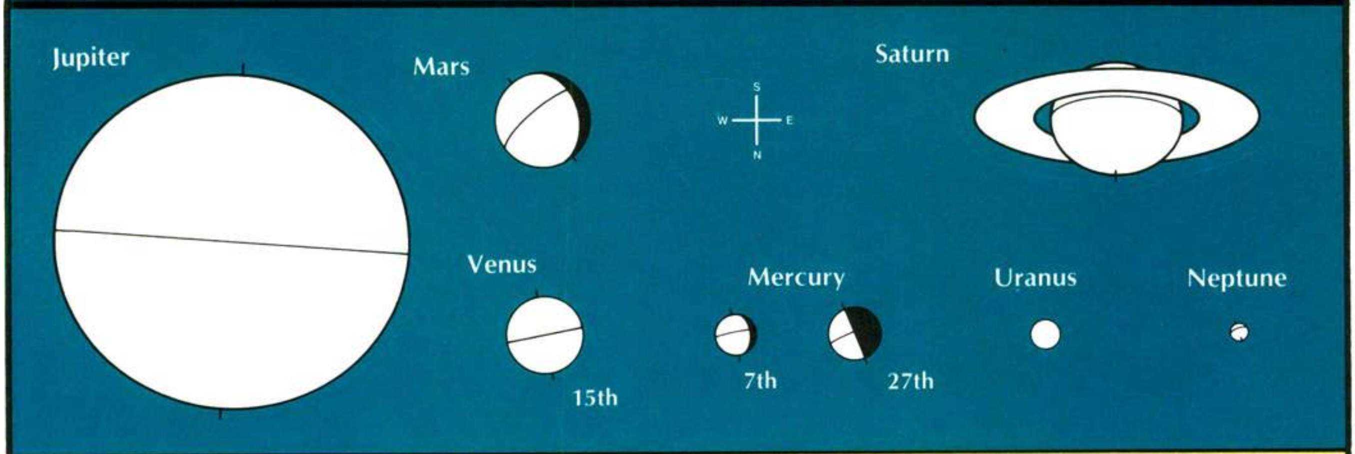
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
NGC-6171	M-107	●	16h 32.5m	−13°03′	8.2	10.0′		
NGC-6218	M-12	●	16h 47.2m	−01°57′	6.9	14.5′		
NGC-6254	M-10	●	16h 57.1m	−04°07′	6.6	15.1′		
NGC-6266	M-62	●	17h 02.2m	−30°07′	6.5	14.1′		
NGC-6333	M-9	●	17h 19.1m	−18°31′	7.8	9.3′		
Barnard 72		☐D	17h 24.0m	−23°38′	—	30.0′		
NGC-6369		■	17h 29.3m	−23°46′	10.4	28″		16.0
NGC-6384		§	17h 32.3m	+07°04′	11.3	4.0′ x 3.0′		
NGC-6402	M-14	●	17h 37.6m	−03°15′	7.5	11.8′		
IC 4665		⊙	17h 46.2m	+05°43′	6.0	55.0′	20	7....
RS Oph		RN	17h 50.2m	−06°43′	4.0↔12.0	Irr.		
Barnard's Star		★	17h 57.9m	+04°24′	9.5	—		
70 Oph		★^{2}	18h 05.4m	+02°32′	4.2, 5.9	1.9″ (1984)		
NGC-6572		■	18h 12.1m	+06°51′	9.0	14.8″		9.8
NGC-6611	M-16	⊙☐E	18h 18.8m	−13°47′	6.5	25′	60	8....
X Oph		LPV	18h 38.4m	+08°50′	6.0↔9.3	334d		
IC 4756		⊙	18h 39.1m	+05°29′	6.0	70′	80	7....

★	*Star*
★^{2}	*Double Star*
●	*Globular Cluster*
⊙	*Open Cluster*
LPV	*Long Period Variable*
RN	*Recurring Nova*
☐E	*Emission Nebula*
■	*Planetary Nebula*
☐D	*Dark Nebula*
§	*Spiral Galaxy*

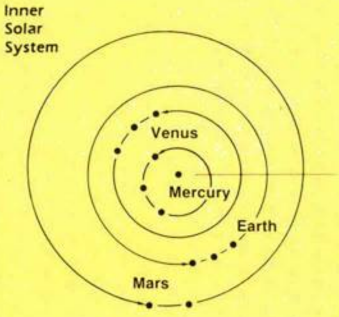
N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.

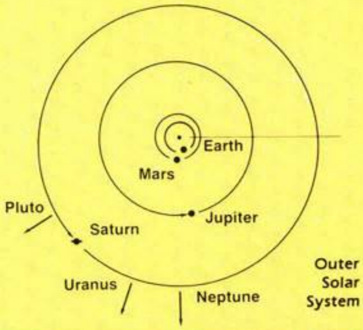

18h
17h
+10°
0°
-10°
-20°
-30°
α
ι
ϰ
X
NGC-6572
NGC-6384
IC 4665
IC 4756
HERCULES
β
σ
Barnard's Star
γ
70
λ
M-12
M-14
η
M-10
Galactic Equator
RS
μ
OPHIUCHUS
τ
ν
ζ
M-107
SCUTUM
M-16
ο
ν
SERPENS CAUDA
ξ
η
M-17
M-18
φ
χ
M-9
M-23
M-24
M-25
ξ
M-21
Ecliptic
M-20
NGC-6369
B72
ο
M-22
M-28
M-8
θ
M-19
SCORPIUS
M-4
SAGITTARIUS
Galactic
Center
M-62
M-6
M-70
M-69
M-7

Planetary Data July 1984


Jupiter
Mars
S
W
E
N
Saturn
Venus
15th
Mercury
7th
27th
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.5′	—	1.02	—	—	99°20.9′	6h 41.6m	23°05.9′
		15	−26.7	31.5′	—	1.02	—	—	112°41.7′	7h 38.9m	21°29.9′
		31	−26.7	31.6′	—	1.02	—	—	127°58.6′	8h 42.4m	18°13.4′
Mercury	☿	1	−1.3	5.2″	93%	1.30	0.34	138°13.8′	108°07.2′	7h 22.9m	23°54.8′
		15	−0.2	6.0″	72%	1.13	0.41	198°26.6′	133°39.7′	9h 09.1m	17°44.2′
		31	0.4	7.6″	49%	0.89	0.46	246°46.2′	154°34.0′	10h 27.1m	8°26.6′
Venus	♀	1	−3.9	9.7″	100%	1.73	0.72	109°21.9′	103°00.7′	6h 59.8m	23°30.0′
		15	−3.9	9.8″	99%	1.71	0.72	132°05.6′	120°13.5′	8h 13.6m	21°06.3′
		31	−3.9	10.0″	98%	1.68	0.72	158°05.8′	139°54.6′	9h 33.9m	15°59.6′
Mars	♂	15	−0.7	12.8″	89%	0.73	1.46	265°23.5′	225°17.4′	14h 51.0m	−18°40.6′
Jupiter	♃	15	−2.7	46.5″	100%	4.23	5.22	279°20.5′	275°41.8′	18h 27.8m	−23°15.6′
Saturn	♄	15	0.5	17.4″	100%	9.53	9.88	225°21.6′	219°14.7′	14h 33.1m	−12°31.2′
Uranus	⛢	15	5.5	3.8″	100%	18.26	19.02	252°05.0′	249°39.1′	16h 34.4m	−21°57.5′
Neptune	♆	15	7.9	2.3″	100%	29.32	30.26	270°11.4′	268°59.9′	17h 58.5m	−22°13.9′
Pluto	♇	15	13.7	0.1″	100%	29.69	29.82	211°21.3′	208°57.4′	14h 13.5m	4°32.1′

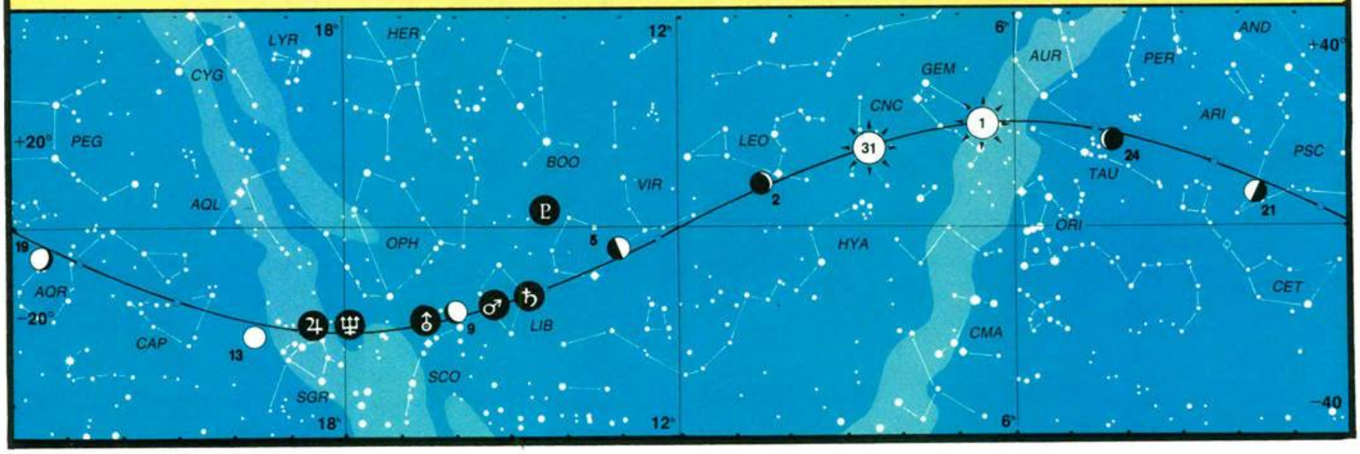

Inner Solar System
Venus
Mercury
Earth
Mars


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune
Outer Solar System

Moon Data

First Quarter. . . . . July 5 at 21:04
Full Moon. . . . . July 13 at 2:20
Last Quarter. . . . . July 21 at 4:01
New Moon. . . . . July 28 at 11:51
First Quarter. . . . . Aug 4 at 2:33

Perigee: July 2 at 22:33. . . . . . 367,298 km.
Apogee: July 18 at 13:37. . . . . . 404,832 km.
Perigee: July 30 at 12:15. . . . . . 362,358 km.


LYR
18h
HER
12h
GEM
6h
AUR
PER
AND
+40°
CYG
CNC
ARI
+20°
PEG
LEO
31
1
24
PSC
BOO
VIR
TAU
AQL
2
21
♇
ORI
19
OPH
5
HYA
AQR
CET
−20°
♃
♆
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♄
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9
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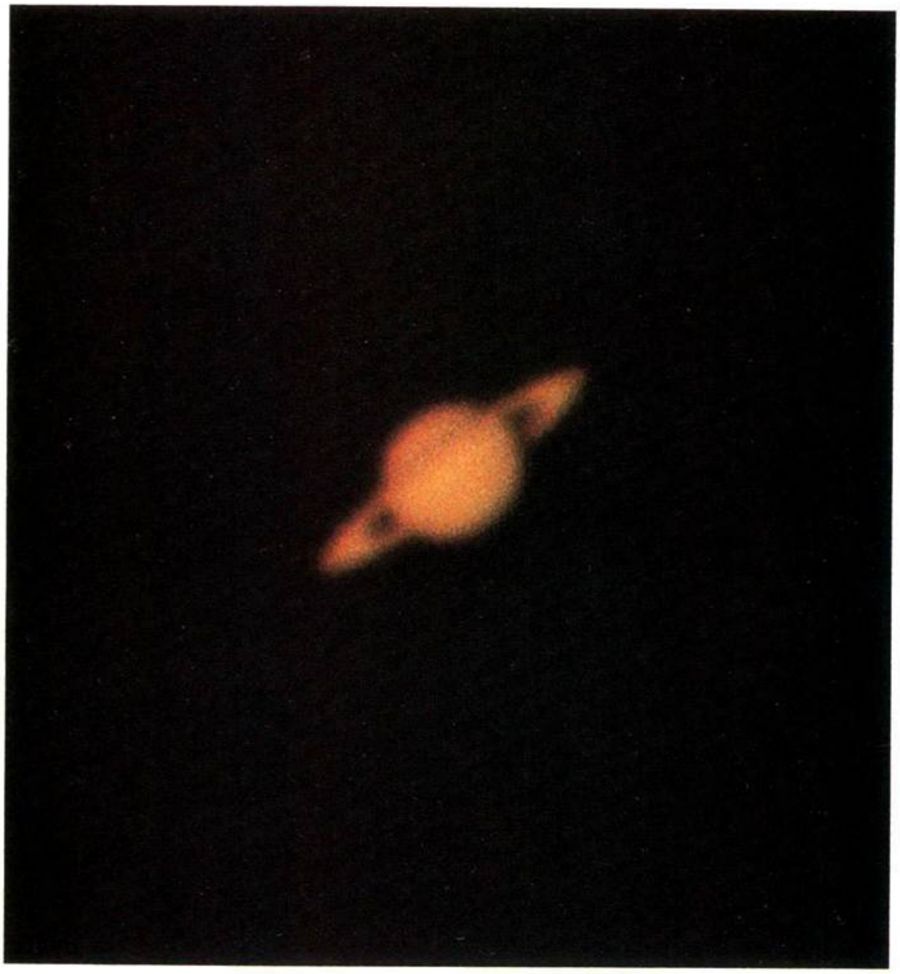
SCO
SGR
18h
12h
6h
−40



Saturn is difficult to photograph: it is dim, exposures must be long, and good seeing is essential. John Steenkamp used an 8-inch Newtonian, Ektachrome 400, and 8 seconds' exposure at f/60.

Mercury

Mercury reaches greatest eastern elongation in the evening sky on August 1 and will be in view — albeit barely — for the whole month of July and part of August. Peak elevation comes around the 21st of July, but it is a scant 5° (45 minutes after sunset). A better elongation for observing Mercury will be the morning one in mid-September.

At 4:50 UT on July 26th, Mercury will pass 49′ of arc south of Regulus. That evening, use a low-power eyepiece to observe them both in the same field of view. Mercury will be a 0.2 magnitude dot, 7″ of arc across and appearing half-lit; Regulus will be a 1.4 magnitude speck of light.

Venus

Venus is still too close to the Sun to be seen except during the day. (For directions on daylight observing, see last April's Backyard Astronomer.) You'll begin to catch sight of it in the evening sky after sunset sometime in August, though the planet won't gain much elevation — and accordingly won't be a good telescopic target — until later in the Fall.

Earth

Earth passes through aphelion on July 3rd at 7h UT, when we will be 152.11 million kilometers from the Sun.

Mars

Mars is now a prominent object in the southwestern sky during the evening hours. Though still remaining bright, it will dim by half a magnitude this month, and its disk will shrink from 14″ of arc to 11″. The autumnal equinox for Mars will occur on July 14th, when the Sun crosses the martian celestial equator southbound. (At the same time, Earth still has a declination of +18° in the martian sky.)

Asteroids

1 Ceres (magnitude 8.6) lies in northeastern Cetus. Its positions:

9th: 2h 49m 23s, 7° 44.3′
19th: 3h 00m 42s, 8° 26.4′

Ceres rises around 2:30 a.m. local daylight time on July 15th.

2 Pallas (9.5) is in south-central Pegasus. Its positions:

9th: 23h 14m 4s, 9° 49.6′
19th: 23h 13m 39s, 9° 24.1′

Pallas rises about 11 p.m. local daylight time at mid-month.

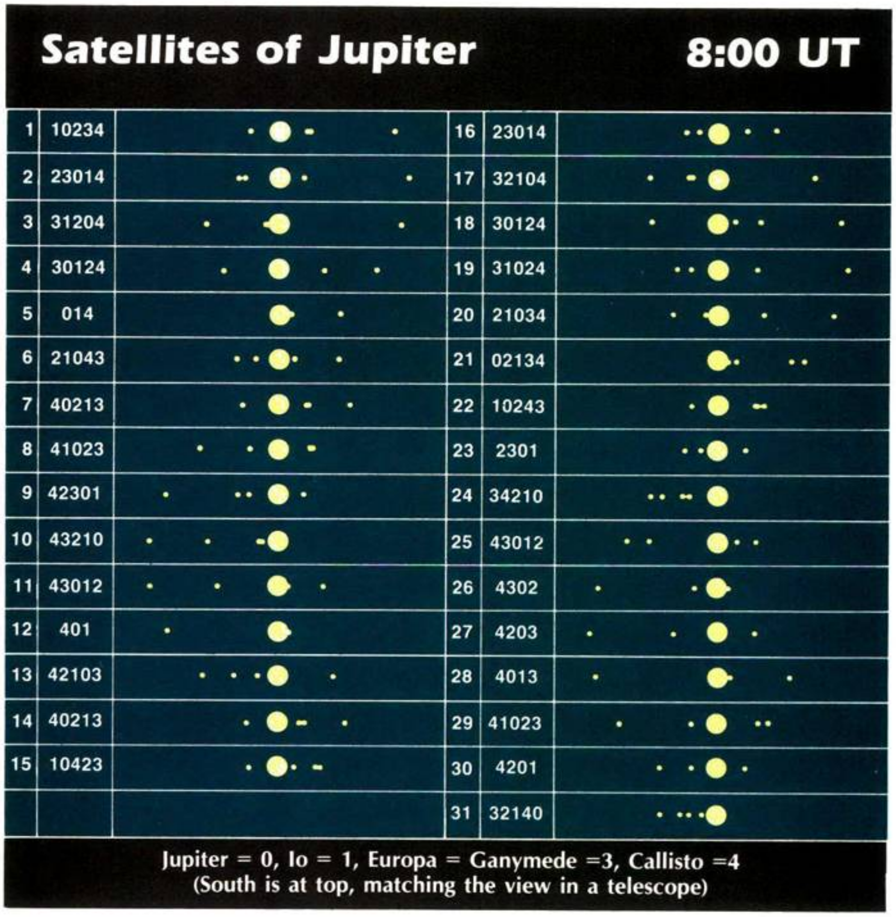
3 Juno and 4 Vesta remain too close to the Sun to be seen this month. Both are in conjunction in August.

For convenience in plotting their positions in a star atlas, asteroid coordinates are given for the epoch 2000.0.

Jupiter

Jupiter's path this month takes it retrograde 2.5° north of 2.8 magnitude Lambda (λ) Sagittarii, the star marking the

Satellites of Jupiter 8:00 UT



1	10234	16	23014
2	23014	17	32104
3	31204	18	30124
4	30124	19	31024
5	014	20	21034
6	21043	21	02134
7	40213	22	10243
8	41023	23	2301
9	42301	24	34210
10	43210	25	43012
11	43012	26	4302
12	401	27	4203
13	42103	28	4013
14	40213	29	41023
15	10423	30	4201
		31	32140

Jupiter = 0, Io = 1, Europa = Ganymede =3, Callisto =4
(South is at top, matching the view in a telescope)

knob of the Teapot's lid. At opposition in late June, Jupiter is big, bright, and loaded with telescopic detail. The part of the ecliptic it lies on never rises very high in the south, but you can work around some of the resultant bad seeing effects by diligently observing whenever you can.

Saturn

Saturn's section of ecliptic has a higher declination, but the planet is now well over in the southwest by nightfall and on the way down. As a result, to see the most of it you can, follow the same practice as with Jupiter — observe as often as possible.

Uranus

Uranus is now about a month past opposition — yet because it lies so far distant, its appearance doesn't change much from month to month: it has a 3.8" of arc disk and is at 5.5 magnitude. Uranus lies in Ophiuchus, a little over 4° north of Antares and about 5 minutes of r.a. east. Its bright greenish disk will stand out clearly from the starfield with anything more than lowest magnification.

On July 9th at 23:21 UT, a gibbous Moon will just miss Uranus, passing about 10' of arc south of it. (From South America, the south Atlantic, and southern Africa, the event is an occultation.) Use low to moderate power eyepieces to observe the two together.

A series of photos of the event taken every few minutes with an equatorially mounted, clock-driven telescope will make a fine demonstration of the Moon's motion — but expect to have exposure problems because of the great difference between the bright limb of the Moon and dim Uranus. With slide film, your best approach will be to expose for Uranus and let the Moon "burn out"; with negative film, do the same, but give the Moon's limb extra exposure in printing. Using 400 speed film and an f/40 optical system (typical for moderate eyepiece projection), start with an exposure of a half second and run up to 10 or 20 seconds.

Right: July's "Best Astro-Photo" is Brant Nelson's shot of the Gamma Cygni nebulosities. He used a 20-minute exposure on hypered 2415, a red filter, and an 8-inch f/1.5 Schmidt camera. Above: This Perseid was caught by Rick Klann with 400 ASA film, a 28mm f/2 lens, and a 7-minute exposure. He was 50 miles north of Detroit.

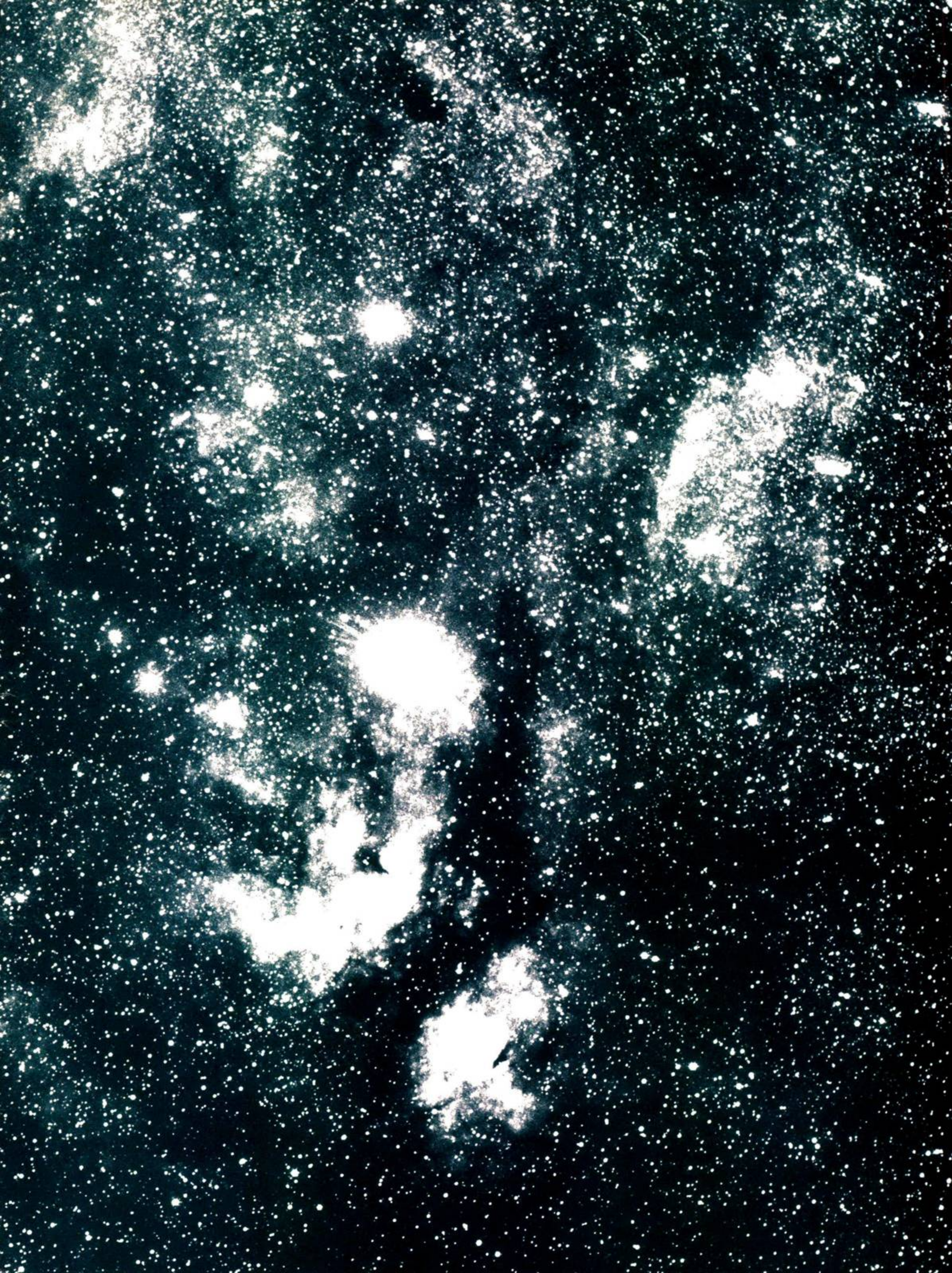
Neptune

Neptune, being more distant than Uranus, is both smaller (2.3") and dimmer (7.9 magnitude); it also lies amidst a richer starfield. Look for it a degree north of M-20, the Trifid Nebula, and about 5 minutes of r.a. west.

On July 22nd at 6:50 UT, Neptune will pass extremely close to a ninth-magnitude star, SAO 186001 (magnitude 8.7; α = 17h 57m 44s, $\delta = -22° 14' 02''$, 2000.0 coordinates). An occultation is probable for North American observers; start watching about 6:00 UT. The middle of the stellar eclipse will probably occur around 6:48 to 6:57 UT, with the occultation lasting about 20 minutes. If Neptune occults the star, you'll see a 0.4 magnitude drop in light. Use high magnifications for best results.

Meteors

The best shower for July is the southern Delta Aquarid, with its radiant in southeastern Aquarius. This shower has a very broad period of activity (from mid-July to late August), but reaches a peak of sorts on July 29th. Well timed this year considering the lunar phases (the Moon is New the day before), the southern Delta Aquarids will yield about 15 to 20 medium-speed, yellowish meteors per hour for observers at dark-sky locations.



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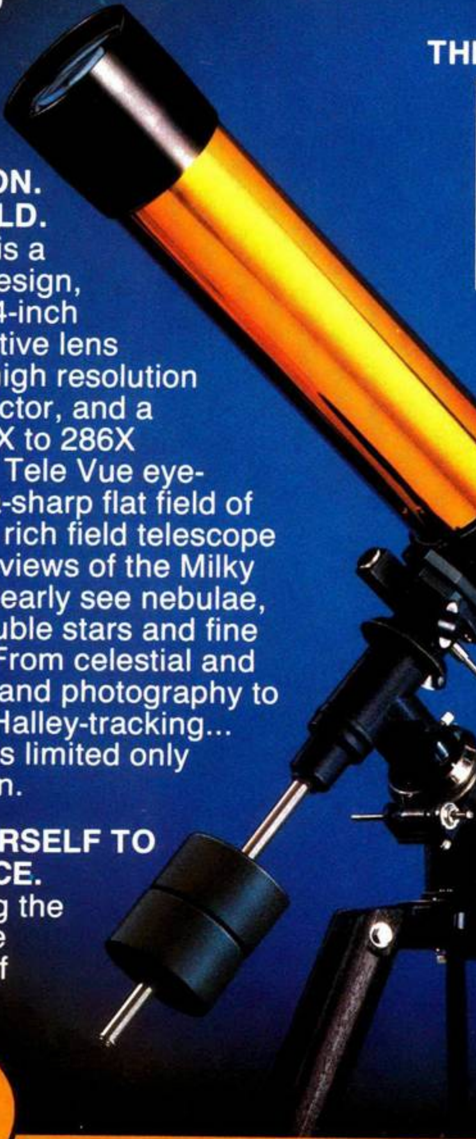

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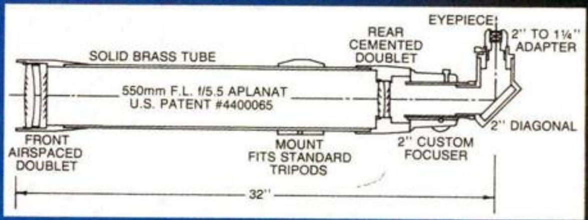
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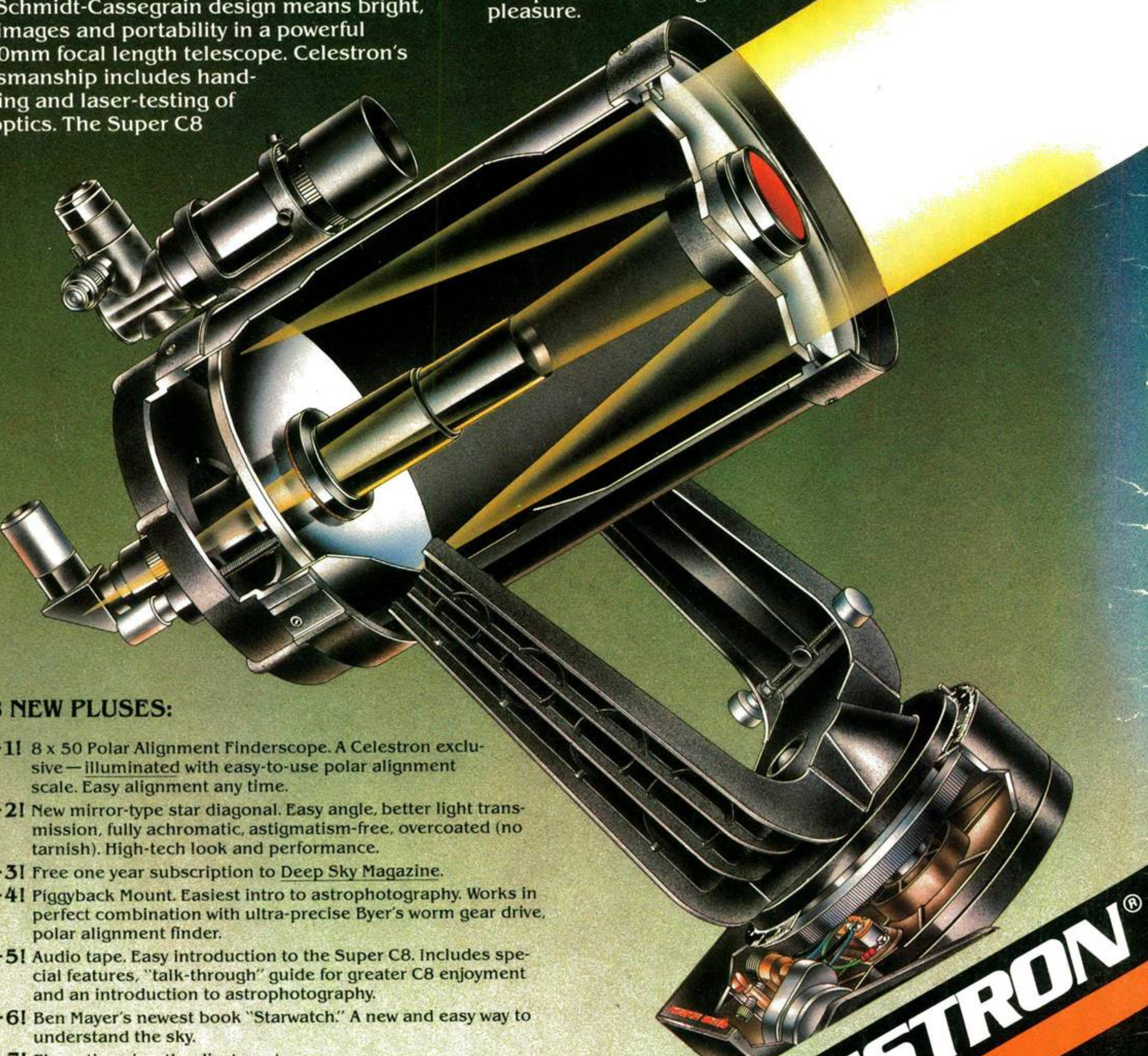
Celestron's world-renowned optical design and Celestron Certified Diffraction-Limited Optics assure you of the best optical value available today. The Schmidt-Cassegrain design means bright, f/10 images and portability in a powerful 2,000mm focal length telescope. Celestron's craftsmanship includes hand-figuring and laser-testing of the optics. The Super C8 features a superb Byer's worm gear drive, the most accurate clock drive available today, a patented (pending) design built with special Swiss machine tools.

But even the finest instrument must be used and enjoyed. So we've taken the mystique out of astronomy.

Owning a Celestron Super C8 Plus is exciting. Now we've added 8 new pluses for even greater pleasure.



8 NEW PLUSES:

+1! 8 x 50 Polar Alignment Finderscope. A Celestron exclusive — illuminated with easy-to-use polar alignment scale. Easy alignment any time.

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+3! Free one year subscription to Deep Sky Magazine.

+4! Piggyback Mount. Easiest intro to astrophotography. Works in perfect combination with ultra-precise Byer's worm gear drive, polar alignment finder.

+5! Audio tape. Easy introduction to the Super C8. Includes special features, "talk-through" guide for greater C8 enjoyment and an introduction to astrophotography.

+6! Ben Mayer's newest book "Starwatch." A new and easy way to understand the sky.

+7! Fingertip azimuth adjustment.

+8! A Latitude scale and bubble level for more ease in polar alignment.

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